ILLUMINATING ENGINEERING

JULY 1956

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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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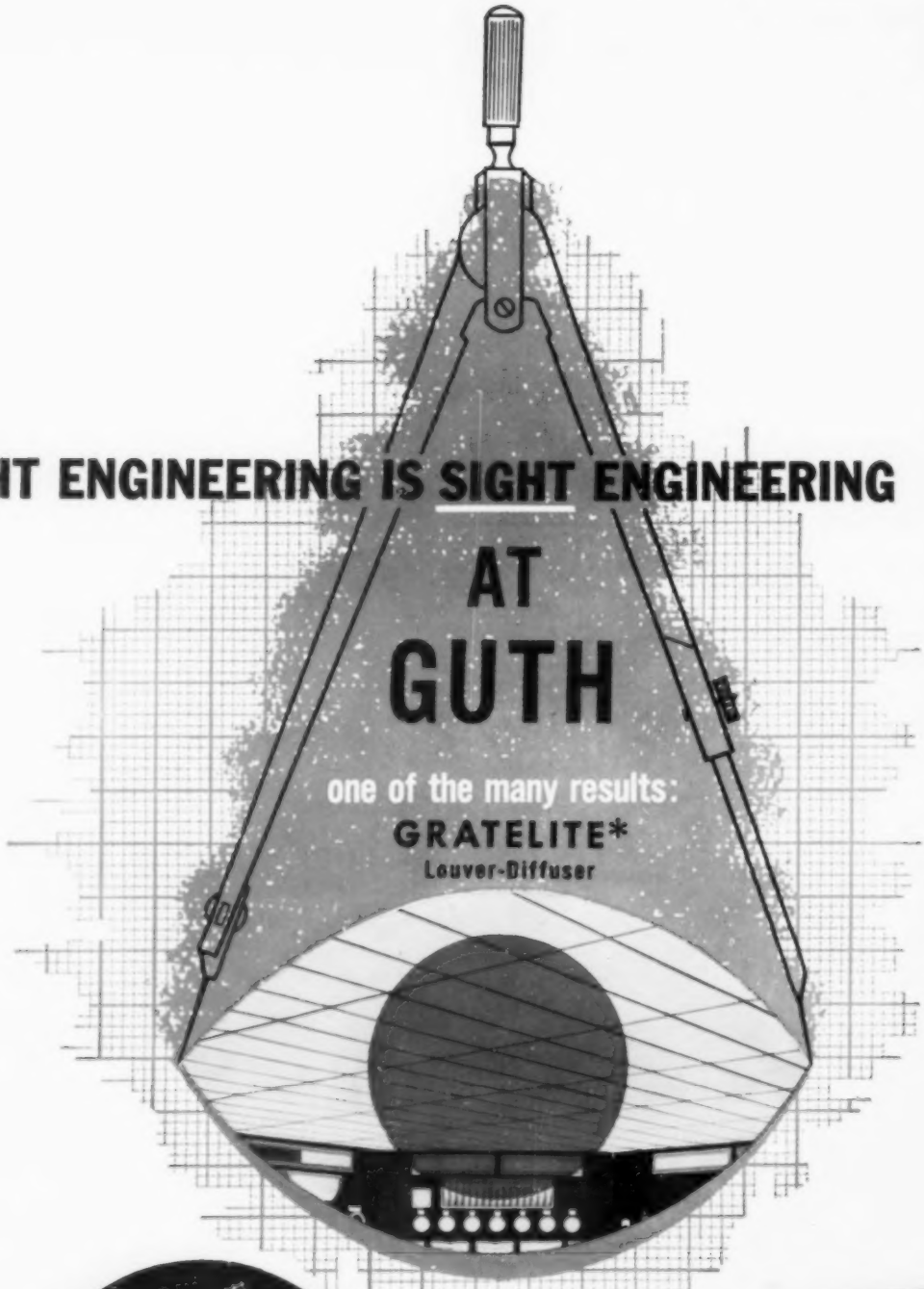

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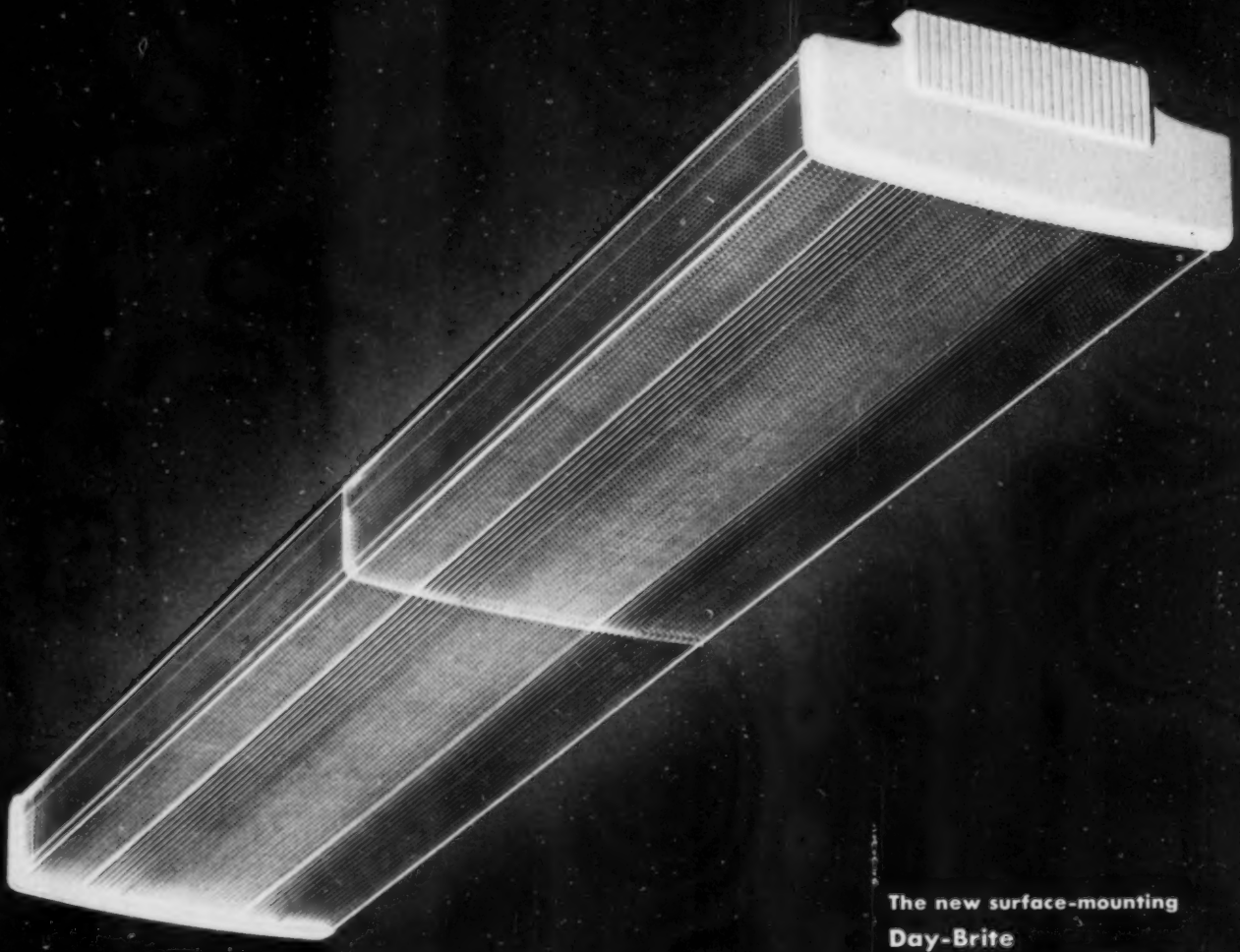

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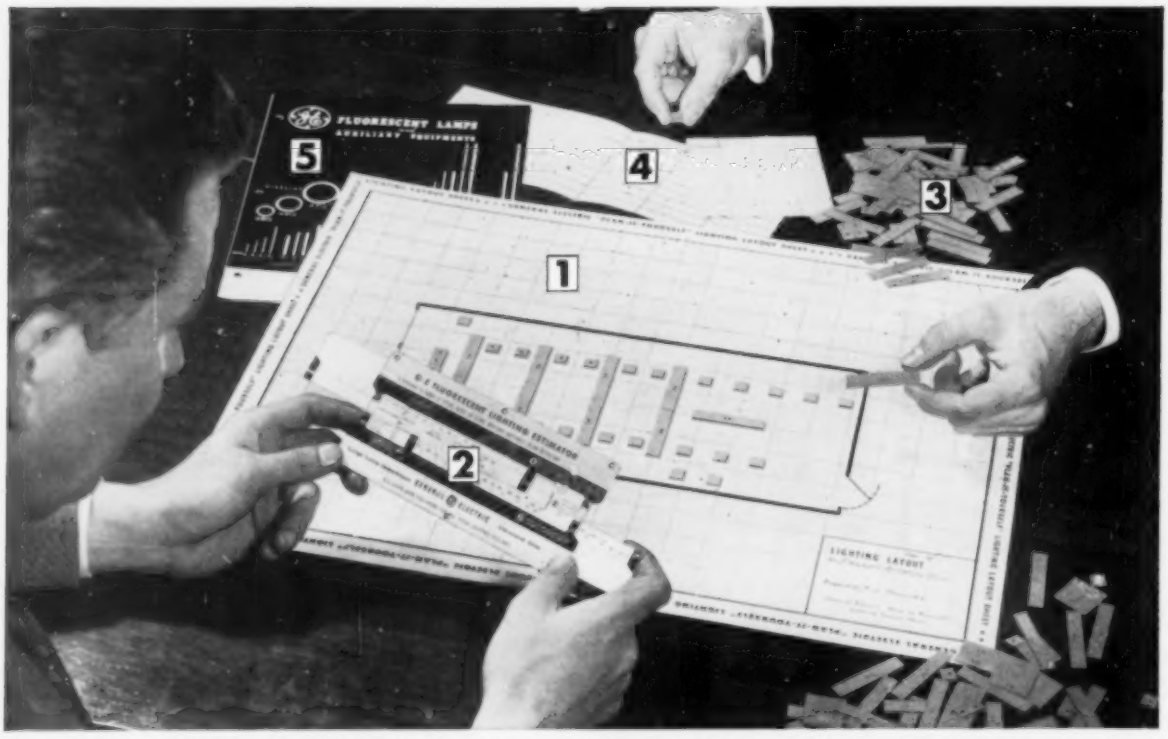

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Engineered Lighting for Demonstration

By J. D. WHITNELL

No matter how good the engineering, a lighting job almost always has to be sold. Principles of good lighting practice must be established in the customer's mind so he can properly evaluate his proposed installation.

It was with this fact in mind that the Arizona Public Service Company began its building program in Yuma, Arizona. Yuma, a rapidly growing town on the western border of the state, was in need of increased utility facilities, particularly since existing buildings were somewhat old, obsolete and too small for the expanding operations.

The program, completed in 1955, was for five buildings: two neighborhood offices, a repair shop for equipment, a warehouse, and a service center to house the managerial and sales staffs, the engineering and the accounting departments and parts of the operating departments.

The dual purpose of the lighting in these buildings is (1) to provide adequate levels of illumination for the various seeing tasks, and a comfortable visual environment; and (2) to demonstrate different lighting systems for prospective customers.

Areas for which lighting systems are demonstrated include: general and specialized offices, reception rooms, conference rooms, auditorium, display areas, control rooms, warehouses, machine shops and yards.

Since the installations have been completed, they have been demonstrated many times. Contractors, architects and engineers use the facilities to show customers what would be the best lighting practice for their own buildings. Lighting practice in the town of Yuma has been improved greatly since this installation was made.

Author: Arizona Public Service Co., Phoenix, Ariz.

Display and circulation areas in Fourth Avenue Office. Over display area is a plastic louverall ceiling with 2½-inch cubical cells. The cavity is 18 inches deep and single-lamp fixtures are mounted on 12-inch centers. Louverall ceiling is mounted at 10 feet. Illumination in 14 x 30-foot area is 150 footcandles. In the circulation area, 70 footcandles are provided at desk height by translucent plastic fixtures with major distribution in an upward direction. The 4-lamp units are mounted 2 feet below the 11-foot ceiling, on 10-foot centers.

Display area and front canopy of Main Street Office. Recessed fixtures in the canopy light the entrance way. Over the display area commercial fixtures are mounted on 3-foot centers with matching accent spots provided. Both louvered units and units with low-brightness glass bottoms are provided. Illumination at floor level is 110 footcandles.

Engineered Lighting for Demonstration

Auditorium. Semi-direct lighting system is supplemented by accent spots, provided so the room can be used to demonstrate various appliances or other merchandise. Recessed troffers over the stage area have low-brightness lenses. Additional spots provide higher illumination levels, which are 60 footcandles in the seating area and 90 on the stage. The relatively high level in the seating area was prescribed by previous experience that small auditoriums are used for a variety of purposes. Standard cove lighting fixtures along the wall supplement the general lighting and provide an interest accent on the wall. Posters can be hung under these units.

Yard. Protective lighting and lighting for necessary night work in the yard is supplied by 1000-watt floodlights, 6000-lumen street lighting equipment and bracket lights on the buildings lamped with 200-watt lamps.

Reception Room. The luminous ceiling in the reception area supplies 35 footcandles, with supplementary illumination for bulletin boards. Halls are lighted with 2-lamp units with plastic bottom panels. Air-conditioning ducts prevented recessing on the low ceiling.

Conference Room. Although ceilings throughout this building are relatively low — 9 feet — suspended luminaires are used for demonstration. Here totally indirect units, each with four 8-foot 430 ma lamps, give an average of 66 footcandles on the table.

Storerooms. Various types of fixtures are used in the storeroom areas for demonstration purposes. Unit shown here has louver shielding; another type system has diffusing plastic shielding.

Assistant Manager's Office. Direct lighting system is demonstrated with 2-lamp surface-mounted fixtures with diffusing plastic bottoms. The 2-foot-square units, mounted in rows of six, supply 60 footcandles.

Sales Office. Although comparatively small in size, this office shows luminaires of various distributions. Recessed incandescent, silver-bowl, luminous indirect, indirect, and direct-indirect fixtures are separately switched so that results can be compared.

Bookkeeping Department. White enamel shells with diffusing Alzak louvers and spine use 40-watt T17 low-brightness lamps. Fixtures are suspended one foot from the 9-foot ceiling, providing 63 footcandles. Similar fixtures, with T12 rapid-start lamps, are used in the meter readers' room.

Engineered Lighting for Demonstration

Foremen's Write-Up Room. The fixture here was chosen for surface mounting, which would still provide some light on the ceiling. Glass side panels allow light to spread. The bottom plastic panels are composed of ⅝-inch cubicle cells for 45-degree louvering. Footcandle level is 50.

Engineering Department. Direct-indirect installation uses the T17 low-brightness lamps in Alzak fixtures, mounted one foot from the ceiling, arranged at an angle of 45 degrees with the walls to minimize shadows on drafting boards. Illumination level is 80 footcandles.

Washrooms. Louvered industrial type fixtures provide 40-60 footcandles in this change room. Experience has shown that janitorial staffs do a better cleaning job when plenty of light is provided. All wall surfaces are painted in light colors, 50% RF; ceilings are 75% RF. Floors also are light in color.

Manufactured Light Vs Daylight For Schoolrooms

By RICHARD F. HAMMEL
LAWRENCE E. JOHNSON

In this paper an architect and an illuminating engineer examine the role of daylight and manufactured light in the schoolroom and conclude that the basic utilitarian light can best be supplied by manufactured light while daylight can function best in providing variation and change in the visual picture.

The authors feel that, in developing designs based on this concept, schools can be greatly simplified in design, flexible in size, shape and orientation, and can have adequate levels of illumination with comfortable visual environments with construction and annual costs at least comparable to designs relying heavily on daylight for lighting levels.

The locale of studies is the Upper Mississippi Valley area. The conclusions drawn should apply to other areas with similar weather conditions and may apply to areas with dissimilar conditions.

The paper is divided into two parts. In Part I the illuminating engineer presents some cost studies and observations on lighting and brightness conditions. In Part II the architect examines the illumination requirements in a schoolroom and how both daylight and manufactured light can be used to perform the function best suited to each.

Part I

A. In General

Several basic types of construction are prevalent in this area. Figs. 1 through 5 indicate some of the fenestration techniques that have been used. One design, Fig. 1, uses clear glass from window sill to ceiling with interior shielding — frequently venetian blinds. This design allows good visual association with the outside when the shielding is not used, but it has been noted that in actual operation the blinds are normally left at a fixed level giving a vision strip appearance with the plane of the blind being varied for brightness control.

Fig. 2 shows a design using a large exterior shield. This design does overcome sky glare to a large extent and does not require the manipulation common to interior shielding. The windows in this case are used to provide the view rather than to admit daylight. Ground reflections would provide the major source of daylight in this design. Interior shades would be required if audio-visual teaching aids are used.

Refracting glass block walls, Fig. 3, have been used in a number of cases to reduce sky glare and to direct light into the room. Studies[1] indicate that with this design ceiling heights should be equal to

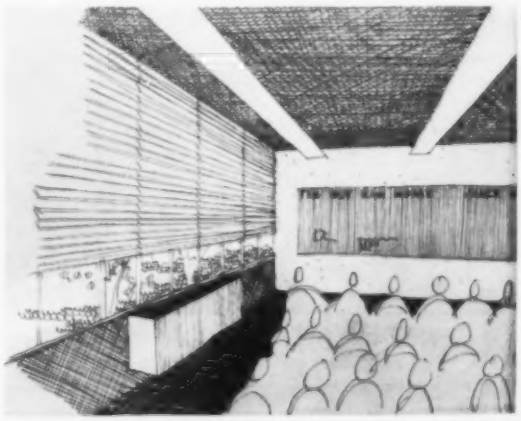

Figure 1. Clear glass fenestration to ceiling, shielded by venetian blinds.

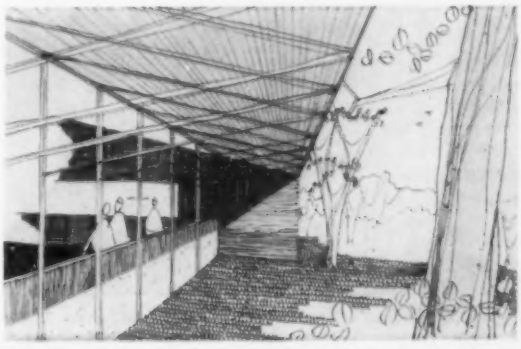

Figure 2. Clear glass fenestration to ceiling with exterior shielding.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 12-16, 1955, Cleveland, Ohio. AUTHORS: Hammel and Green, Architects, St. Paul, Minn., and Northern States Power Co., Minneapolis, Minn., respectively.

one-half the room width for best results. This 2 to 1 ratio of room width to height may limit the designer in developing room proportions dictated by the requirements of the room. Adding of shielding to control brightnesses with low incident sun and for darkening the room when using projected pictures should be considered.

Clerestories, Fig. 4, have been used in some schools in this area using either clear glass or refracting glass block. These devices must be generous in size to contribute significantly to lighting levels. The added cost of this construction and the problem of controlling brightnesses in the room should be considered. Maintenance is also a factor.

Plastic ceiling domes, Fig. 5, have been used in some instances to supplement lighting levels in the inner portion of rooms. Frequent attention to shielding devices to compensate for excesses or deficiencies in daylight can be expected.

All these techniques indicate that designers are being called upon to exercise considerable ingenuity in trying to gain the advantages of daylight while overcoming attendant disadvantages. The varying degrees of success attained indicate that perhaps an entirely new approach should be considered.

The type of classroom design which is possible when manufactured light is used to provide basic lighting levels is shown in Figs. 6 and 7. The room is 25 feet along the window wall and 34 feet deep, has a 10-foot ceiling, and uses 4-foot vision strip with 4-foot overhang. The so-called utilitarian lighting is planned entirely from a manufactured source — in this case a baffle lighting system of some 60 to 75 footcandles. The overhang provides shielding for sun altitudes down to 45 degrees. For

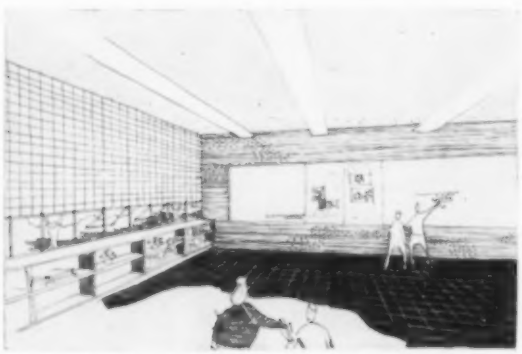

Figure 3. Directional glass block with vision strip.

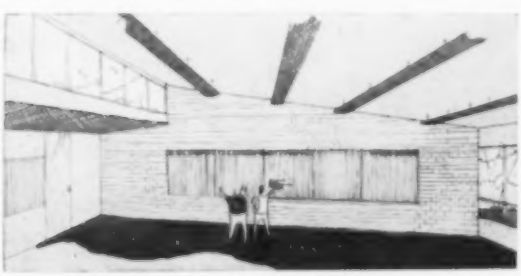

Figure 4. Clerestory lighting.

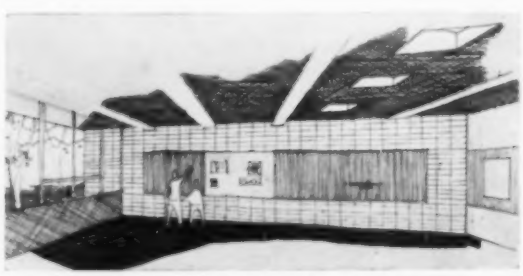

Figure 5. Plastic ceiling domes.

Figure 6. Manufactured light provides adequate levels of light in this room. Four-foot-high windows allow for good visual association with outdoor scenes.

Figure 7. Four-foot overhang provides sun shielding for sun altitudes down to 45°. Window shades draw up from window sill to provide for shielding of lower sun positions or to darken room.

lower sun positions or to darken the room, shades are drawn up from a recess in the window sill. This room allows a more compact plan which is low in cost, simple in construction, flexible in size, and requires a minimum of manipulation of shading devices to compensate for daylight variations. The question arose in this case whether the cost of operating lights continually during class hours was a major problem. We have endeavored to answer this with some cost figures.

B. Cost Analysis

Four classrooms, Type A, B, C and D, Figs. 8, 9, 10 and 11, similar to those already discussed were compared on a basis of amortized construction cost, heating and lighting costs.[2] Equipment common to all types was not included in the comparison. All rooms were 24 ft x 32 ft in size with a 10-foot ceiling except Type B where a 12-foot ceiling was used to utilize light from glass block wall. Types A and B have long side of room to weather; Types C and D the short side, effecting a noticeable saving in construction cost and heat loss. Venetian blinds were used for daylight shielding.

B-1. Building Costs

(See Appendix A for construction outline.)

Assumptions: Building amortization—50 yrs. @ 3% interest or $38.87 per $1,000 per year.
Plastic ceiling domes—20 yrs. @ 3% interest or $67.21 per $1,000 per year.
Blinds—10 yr. amortization @ 3% interest or $117.23 per $1,000 per year.

		Initial Cost*	Yearly Cost
Type A	Base Cost*	$8,608.00	$335.00
	Shielding	168.00	20.00
	Total	$8,776.00	$355.00
Type B	Base Cost	$8,524.00	$331.30
	Shielding	216.00	25.00
	Total	$8,740.00	$356.30
Type C	Base Cost	$7,880.00	$307.00
	Shielding	190.00	22.00
	Plastic Domes	480.00	32.00
	Total	$8,550.00	$361.00
Type D	Base Cost	$8,038.00	$312.00
	Shielding	54.00	6.00
	Total	$8,092.00	$318.00

*Does not include construction or equipment common to all types

B-2. Heating Costs

Assumptions: 7,870 degree days per year (September-May)
70-degree design temperature.
Fuel cost—$1.00 per million BTU delivered to room.

	Coefficient of Transmission—U	Cost per Square Foot per Year
Masonry	.32	$.0565
Glass Block	.56	.10
Window Glass & Plastic	1.13	.20

TABLE I — Summary of Annual Costs (to nearest dollar).

	Building*	Heating	Lighting and Lamps	Building, Heating Lighting
Type A	$355.00	$50.00	@ 200 hrs. — $14.00	$419.00
			@ 400 hrs. — 28.00	433.00
			@ 600 hrs. — 42.00	447.00
Type B	$356.00	$44.00	@ 200 hrs. — $14.00	$414.00
			@ 400 hrs. — 28.00	428.00
			@ 600 hrs. — 42.00	442.00
Type C	$361.00	$44.00	@ 200 hrs. — $14.00	$419.00
			@ 400 hrs. — 28.00	433.00
			@ 600 hrs. — 42.00	447.00
Type D	$318.00	$27.00	1,000 hrs. — $70.00	$415.00

*Does not include total building cost.

Heating Costs per Year:

Type A	Wall	$32' \times 3' \times .0565$	=	$ 5.42
	Window	$32' \times 7' \times .20$		44.80
				$50.22
Type B	Wall	$32' \times 3' \times .0565$	=	$ 5.42
	Window	$32' \times 3' \times .20$		19.20
	Glass Block	$32' \times 6' \times .10$		19.20
				$43.82
Type C	Wall	$24' \times 3' \times .0565$	=	$ 4.07
	Window	$24' \times 7' \times .20$		33.60
	Plastic domes	3×10 sq. ft. $\times .20$		6.00
				$43.67
Type D	Wall	$24' \times 6' \times .0565$	=	$ 8.15
	Window	$24' \times 4' \times .20$		19.20
				$27.35

B-3. Lighting

Assumptions: 21 fixtures—2 lamp, 40-watt direct-indirect fluorescent.
100 watts per fixture.
Lamps—$1.00 each installed, 7500 hours life.
Energy Rate—$.03 per kwh.

*Lighting Cost Calculations:**

Type A, B, C	—200 hrs. per yr.—operation and lamps		$14.00
	400	Ditto	28.00
	600	Ditto	42.00
Type D	—21 fixtures, 1,000 hours operation at $.03 per kwh	=	$63.00
	Lamp cost—		
	42 lamps $\times \frac{1000}{7500} \times$ $1.00	=	5.60
	Total lighting and lamps per year		$68.60
			(assume $70.00)

*Operating hours for Type D were based on 1,000 hours per year. (180 days @ 5 hours per day + 100 hours). Operating hours for Types A, B, C are shown for 200, 400 and 600 hours since no data is available on actual burning hours when daylight contributes to the illumination. It was observed, however, that the determining factor in whether or not lights were operated was not necessarily the illumination level alone but also depended on brightness distribution in the room. Very few teachers, to say nothing of trained illuminating engineers, would be able to estimate the footcandle range in a classroom so they would be able to use the lights only when the increased level was needed, whatever that level might be. However, they could determine whether the brightness pattern was comfortable or interesting to them and if the room looked better with the lights on they would be used even though a meter might indicate adequate levels without it.

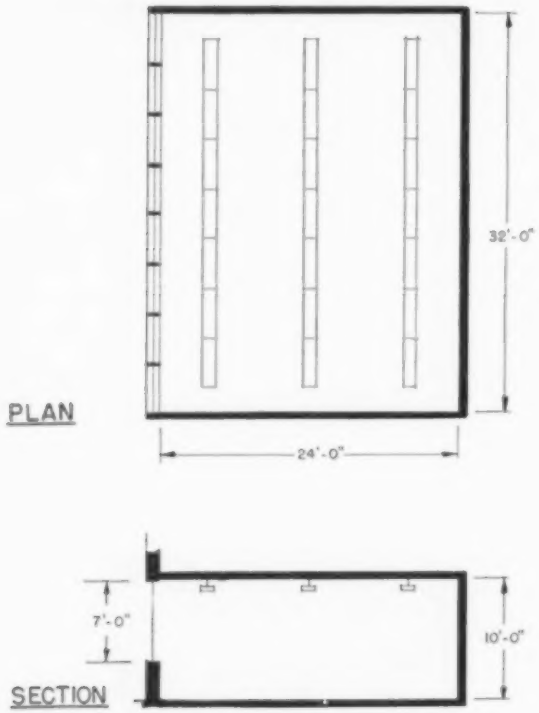

Figure 8. Type A classroom used in cost studies. Clear glass fenestration.

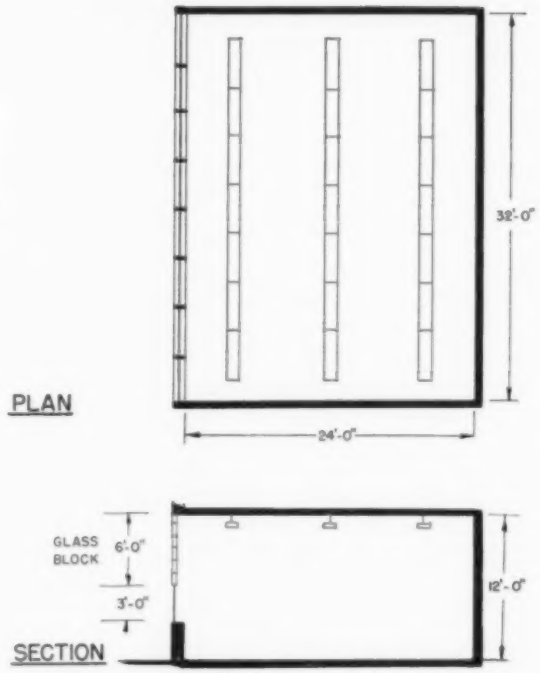

Figure 9. Type B classroom used in cost studies. Glass block with vision strip.

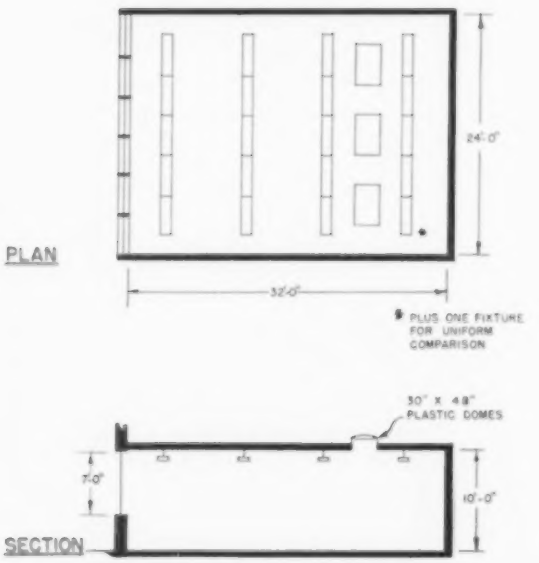

Figure 10. Type C classroom used in cost studies. Clear glass fenestration with plastic ceiling domes.

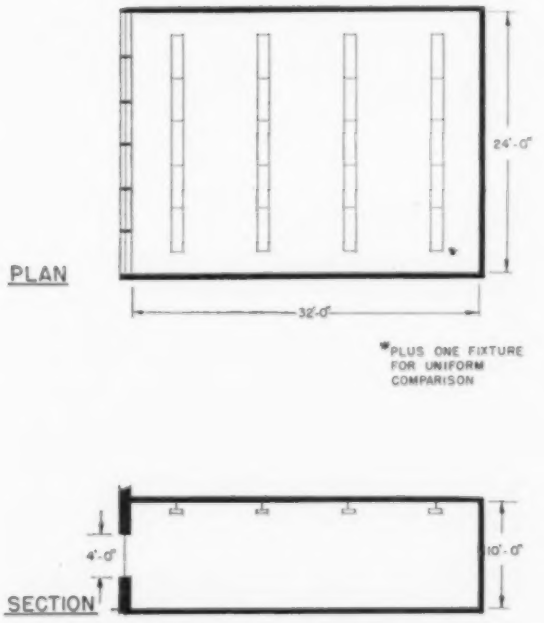

Figure 11. Type D classroom used in cost studies. Four-foot clear glass vision strip. Lighting from manufactured sources.

It is realized that construction, heating and lighting costs are not a large factor in the overall cost of education, but they do receive serious consideration. These comparisons are presented here, however, primarily to indicate that operating cost need not be a deterrant to considering the designs relying exclusively on manufactured light for lighting levels.

C. Footcandle Readings

The variations in outside brightness conditions and adjustment in shielding devices made comparisons of lighting levels difficult or not too meaningful. However, under actual conditions we found the following variations in daylight footcandles during class hours on the outside, center and inside rows of seats: On a clear day, Type A — 310-130-55 (blinds down and adjusted); Type B — 220-170-100 with incident sunlight, 70-36-19 with no incident sunlight; Type C — 1000+-270-180 (with incident sunlight, blinds up). On a cloudy day, Type A — 50-30-14 (blinds down and open); Type B — 23-9-5; Type C — 50-30-7 (4 feet from centerline of plastic dome). In Type D with 60 footcandles of manufactured light we had the following levels: On a clear day, 200-88-70; cloudy day, 80-65-60.

Again no definite conclusions are drawn except to indicate the variation that can be expected under varying daylight conditions and that satisfactory levels of light with considerable uniformity can be had using manufactured light.

D. Visual Comfort

Several things prevented our making a detailed analysis of visual comfort comparisons in the several types of rooms. Varying conditions of daylight brightness, external plantings, buildings, etc. made comparisons non-uniform. Also the application of visual comfort factors to visual fields with a large unbalance in flux distribution between the right and left portions of the field has not been proven.*

We did calculate the visual comfort responses (VCF)[3] for actual conditions from positions at the inside wall looking out, however. When outside brightnesses were relatively low—around 300 footlamberts—or when control devices were used to keep these brightnesses down, the calculated responses were good for all types, ranging from 70 to 80 per cent. When outside brightnesses were relatively high, 750 to 1200 footlamberts, and no control devices were used on window or glass block, all comfort response calculations were low — below 10 per cent. Studies under controlled conditions might make comparisons possible.

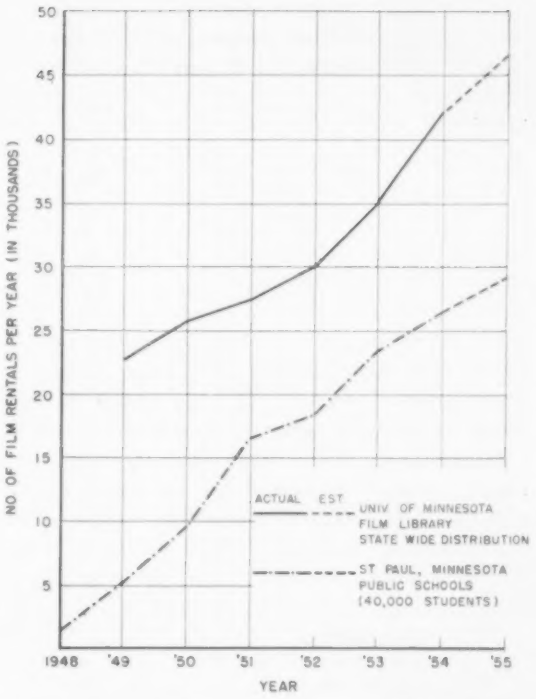

Figure 12. Trend in use of audio-visual films indicates that provisions must be made in schoolrooms for their use.

With the trend towards random orientation of seats in all grades, it becomes imperative that brightness patterns from all viewing positions receive additional consideration. It is possible to have comfortable conditions on bright days from all angles of view but control devices must be planned for shielding windows, glass block and other luminous surfaces.

A considerable point has been made about control of daylight for the use of audio-visual teaching aids which are becoming so popular in some teaching programs. Fig. 12 shows the trend in use of films in the St. Paul, Minnesota public schools and from the University of Minnesota film library. Special projection rooms apparently do not meet the needs of A-V programs. To be used effectively, authorities agree that A-V work should be carried on in the individual classrooms. Daylight screens have not proved satisfactory for competing with room brightnesses so it appears that all rooms should have blackout facilities. Almost without exception classrooms in our area relying on day-

*H. L. Logan states that visual comfort factors (VCF) of the Logan-Lange Method have proven out only when the unbalance is no greater than about 2 to 1 (65% - 35%). In all cases we exceeded this for a rear center viewing position.

light have had no provisions for darkening the rooms. The controlled window areas of Type D classrooms make darkening a simple procedure.

Part II

A. Economy in the Use of Manufactured Light

We have in the first part of this paper explored the economics of classroom constructions in which various lighting techniques are used. These studies indicate that classrooms in which manufactured light is properly utilized are less expensive than "daylighted" rooms. We have noted that these rooms have more uniform lighting, a somewhat smaller annual cost, good comfort conditions, and are more adaptable to modern teaching techniques.

There are also substantial economies and functional advantages possible in the design of the school-building itself by the proper utilization of manufactured light. These economies are substantial and involve both first cost and owning cost. The functional advantages are a more compact and flexible school building.

B. Light and Delight

Before we examine further these economies and functional advantages, it will be necessary that we consider two uses of light in school buildings. The primary use is for lighting for seeing, the secondary use is for lighting for effect or delight. The two are of course closely related, but they are not necessarily the same thing.

Lighting for seeing is that light required to see the book, the chalkboard, the teacher, the basketball, the crayon. It is functional lighting, using a narrowly pragmatic definition for "functional." For this purpose we want a reliable, controllable, glareless and efficient light source.

Lighting for delight in the school building, as in any successful piece of architecture, is the element of change, or surprise. The student may gain this by changing classrooms, as he does every hour in the high school, or by beginning a new activity in the same room. He may gain it by walking through a brightly lighted corridor on the way to the cafeteria with the sunlight streaming unsuppressed through the corridor walls. In successful buildings the student retains a kinship with and awareness of the out-of-doors and contact during at least part of the day with the primary creator of our visual environment, the sun. This "delight" is not necessarily sunlight or daylight, it may be from other sources, but it should be considered separately from lighting for seeing.

For many years now we have not always, in schoolhouse construction, made this distinction. Although schoolhouses are not the only major construction type in which the distinction between light and delight has not been made, it is the only one in which daylighting has been emphasized to a great extent.

That this distinction has not been a concern until relatively recently is probably because electric lighting has not been an efficient instrument in the schoolhouse for much more than a decade. No one should expect that its growing usefulness would have been fully explored.

C. Daylighting as a Criterion

One of the unfortunate results is a confusion of criteria in the judgment of school buildings. Even after the advent of reliable manufactured lighting, the most important single criteria for judging the success of a classroom or a school building seems to be the degree to which it is daylighted. People think a daylighted school is a "good" school. Daylight schools include schools that are toplighted with skylights or plastic domes, clerestories, by borrowed lights, by glass blocks whether in the wall or the roof, or by some other similar device. Another unfortunate result of daylighting as a criterion is that in the typical schoolhouse electric lighting enters the planning picture only after most of the budget (and the budget is usually very tight) has been spent for daylighting devices. These daylighting devices only work in the daylight, and therefore, not at night time, or on dark days. In our own area of good clear weather, about 38 per cent of the days during the school year are too dark to permit daylighting devices to function properly even in the daytime. The effectiveness of daylighting devices depends on such items as the brightness of the sun, its angle with respect to the device, degree of overcast, cleanness of the glass block or other device, time of the day, or the season of the year, seems frequently overlooked. It appears that the economics of the picture, when considering all costs, is often overlooked. Daylight is not "free" when there are increased construction costs necessary to utilize it.

D. No Other Building Type Uses "Daylighting" as a Criterion

No other building type, besides the school building, is really judged by its daylighting techniques.

Our factory designers have largely forgotten about daylighting devices such as the sawtooth roof, monitor, the glass-walled factory in the interests of economy, easier maintenance, and better lighting for seeing.

Office buildings are seldom lighted with glass blocks above vision strips, with clerestories, or other daylighting devices. Nevertheless, today's modern office building has received careful attention by both the architect and the client to make it a more pleasant and efficient place to work. Daylighting is not considered sufficiently important to consider as light for seeing in the office building today. Even such buildings as Lever House and the United Nations building in New York, with their walls of glass are not presented as better buildings to see in because of their glass walls, for the windows are closed off with drapes and venetian blinds. Here glass is for architectonics but not for lighting for seeing.

Hospitals and allied structures such as clinics, are becoming less involved with daylight, and are seeking through the use of manufactured light even better means of lighting increasingly difficult tasks. The operating room is now windowless, so are the labs. The patient's rooms, the day rooms, the lounges, areas where delight as well as light for seeing must be provided have windows, but the planners do not assume that the patient must be bathed in sunlight from windows reaching to a 12-foot ceiling, but only that a view and pleasantness be achieved.

Churches, of all building types, as designed by some of our more sensitive architects probably illustrate most clearly the distinction between light and delight. Here the designer is faced with the problem of achieving a mood of worship and reverence, and with the functional problem of providing the illumination necessary to witness all the activities involved in church ceremonies, whether it be the bridal procession or the sacraments at the altar. For most of the activities manufactured light does the best job; in fact no other source is generally even considered. But the designer will use daylight or sunlight crossing the nave and to highlight the altar, or illuminate a cross. This illumination may also be from a manufactured light source, but in any case, it is not lighting that is required for seeing, but lighting that assists in the development of the spatial qualities of the church or accents important items in the room. This is light that delights.

Likewise in the school building, for seeing the book, the chalkboard, the teacher, electricity provides the only source of light which can be relied upon to furnish controlled quantities and qualities of illumination. In the school as in the church we must furnish delight. In the church it is a worshipful surround; in the school the student should be aware of the changing pace and moods of nature, of his kinship to the world outside. The sun must enter spaces in the building. But let us make the distinction between what the sunlight and what the electric light does. We must assign to each the job it does best. Reliance on daylighting instead of manufactured light in providing lighting for seeing has made impossible many basic economies in schoolhouse planning, for the desk lighted with daylight can never be very far from a window, as a result of which our schools are long, drawn out affairs with long corridors and correspondingly great amounts of exterior wall surfaces.

E. Lighting for Use

We suggest that a more proper criterion for use in the judgment of school buildings must be proposed; one that is not ambiguous. We suggest that this criterion might be: How well is the space lighted for the use for which it is intended. This is the idea of "lighting for use" which has been found a powerful tool in the hands of the architect and the illuminating engineer.

By lighting for use, we mean providing that type and quality of lighting necessary for use of the room occupants, considering their physiological and psychological needs. This definition requires that all of us involved in lighting seek further into what these needs are.

This proposal frees the architect of the restrictions in the school building plan which have been placed upon him by reliance upon daylighting. It makes possible shorter, more compact, and therefore less expensive buildings to construct. It makes possible comfortable, more flexible, and useful classrooms. It makes possible savings in the owner's operating costs through significant reductions in the maintenance problems frequently associated with daylighting techniques, and reductions in heating costs.

F. Classroom Shapes Should Be Dictated by Classroom Function

Classrooms today are becoming differentiated to a great degree; they are also larger. There are classrooms for kindergarten pupils, home economics students, the study of wood-working techniques, for physical education, and for such activities as watching the senior class present its one-act play, to mention a few. Few of the rooms (we really believe that *none* of the rooms) designed for these activities fit well into the traditional 22-foot or 24-foot deep classroom dictated by most daylighting techniques. All of these room types and uses are adaptable to existing techniques in the use of manufactured light; its use makes it possible to proportion the room to the activity taking place in the room independent of the relationship between

window wall and room depth. With the use of manufactured light it is possible to make the kindergarten exactly that shape which its function as determined by the educators requires. The home economics department need not be a ribbon of a room 24 feet deep and 60 feet in length, but can be an easily supervised and functional space perhaps 35 feet deep and 40 feet in length. The same planning approach is possible in all of the various rooms in the school providing manufactured light is used as lighting for seeing.

One thought should be entered here about the importance of rooms other than the so-called "classroom" in today's school buildings. In the typical elementary school only about 40 per cent of the total building area is "classroom" area. In the high school the proportion is even more surprising; less than 20 per cent of the total building area is in "academic" classrooms. The other spaces are gymnasiums, shops, music rehearsal rooms, auditoriums, cafeterias, kitchens, corridors and so forth. The adaptation of daylighting techniques to these areas would require such contortions in building plan and structure that daylight has not been seriously considered in these areas.

G. Overall Building Design Should Be Dictated by Function

The designer who utilizes the idea of lighting for use with manufactured light as his primary tool, need not confine his imagination to the "in-line" arrangement of rooms in the planning of a school building as has been dictated in the past by the limitations of daylighting devices. He may create far different plan types than the spread-out "finger" plans or snake-like plans now common. The use of manufactured light as the source of light for seeing makes possible a more functional school building as well as a more functional classroom.

H. Two School Plans Examined

In order that this freedom in planning be made more clear, we submit the plans of two schools, Figs. 13 and 14, designed around the theory of light for use.

Fig. 13 is of an elementary school. The compactness of the plan is readily apparent. Rooms which would gain little from an outside view are placed in a center core. In comparing this design with so-called conventional designs where daylight exposure is planned for each room we found the external wall surfaces were reduced by about one-third resulting in considerable saving in construction and maintenance costs.

Fig. 14 shows the first floor plan of a junior high school which also takes advantage of this concept. In this plan certain of the corridors are exposed to the outside and students have the change of pace from an outside view between class periods.

Our experience with existing school plants indicates that their obsolescence is in large part due to inability to adapt existing buildings to changing needs. Thirty years ago a typical high school had a principal who was assisted by one clerk as its entire office staff. Today the same school has a minimum administrative staff of eight persons. Likewise, the high school today has far more elaborate facilities for industrial arts, home economics, music, art, crafts, physical education, and in-school dining to mention a few. The academic classrooms in 1920 were from 600 to 700 square feet in area, today they are 900 to 1000 square feet in area. This experience indicates that one criterion to use in the judgment of a high school plan is its ability to adapt to changing space requirements, including space, size and use.

By utilizing manufactured light, the designer of this school, Fig. 14, has been able to assemble the

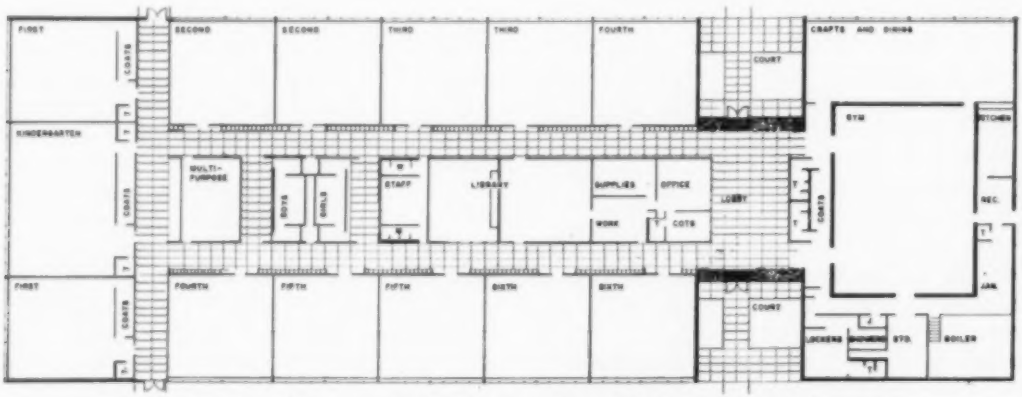

Figure 13. An elementary school using manufactured light as a basic light source.

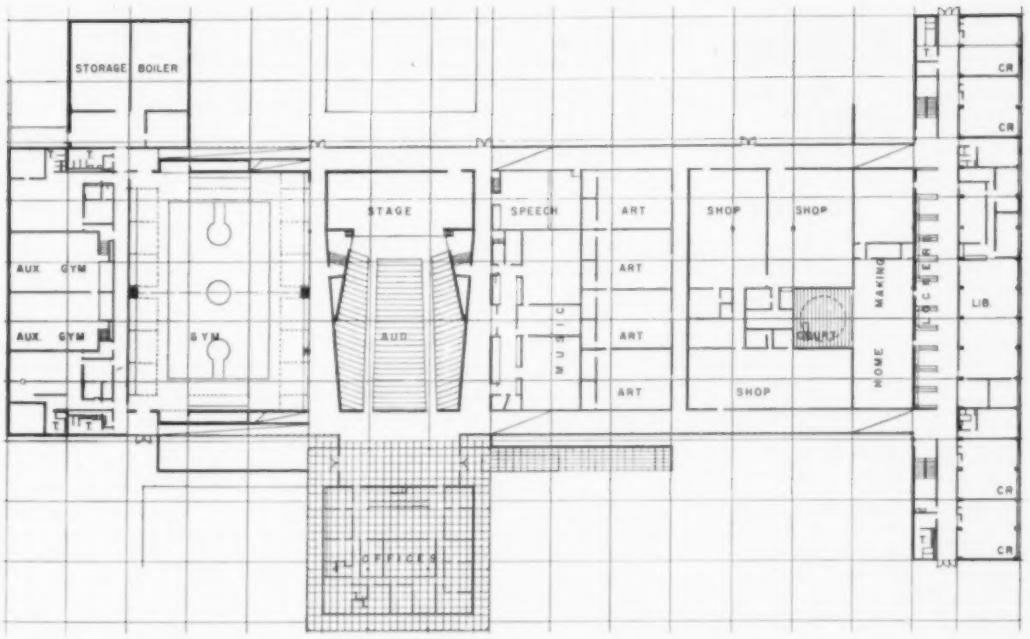

Figure 14. A junior high school using manufactured light as a basic light source.

arts areas (music, fine arts, industrial arts, home making, and speech) into one large area. Each of the spaces in this area is planned for its most functional arrangement without regard to window lighting and the rooms can assume the square shapes most desirable for these activities. In addition the grouping of the areas in one large block makes possible future rearrangement of spaces with a great degree of flexibility. These factors of flexibility are extremely important in the high school as stated above and should serve to increase the useful life of this school by retarding obsolescence in plan arrangement.

The classroom wing is traditionally planned in the sense that each classroom has exterior exposure, but again here the rooms are deeper than is easily possible with daylighting techniques (thirty feet) which will permit future educators to assemble three rooms into two without obtaining unsatisfactory room proportions. The ceiling height in these thirty-foot-deep rooms is 9 feet 0 inches with recessed fluorescent troffers providing approximately 60 footcandles of light, average maintained.

A function of the compactness of the plan of this school is a reduction in student travel and better relationships of school facilities. Reduction in student travel is extremly important in the high school as students change classrooms each hour, and somewhat less important in the elementary school.

J. Conclusions

The use of manufactured light for the schoolroom, independent of daylight, and the proper adaptation of the idea of "lighting for use" makes possible more compact and less expensive school buildings that are pleasant, functional, and adaptable to future change.

Appendix A — Construction Outline

(See B-1, page 496)

The standard construction details for the four types of classrooms are as follows: (1) 20-year bond pitch and gravel roof; (2) 1½-inch rigid insulation; (3) galvanized 22 gage metal deck; (4) steel joists on steel frame; (5) half-inch acoustic tile ceiling on gypsum lath (contact ceilings); (6) asphalt tile floors, one-eighth-inch, C grade, with rubber base; (7) 4-inch concrete slab on grade; (8) 6-inch gravel fill below slabs; (9) exterior pipe tunnel (4 ft x 4 ft); (10) reinforced concrete (3000#) foundation walls (12 inches) and footings; (11) concrete block tunnel walls (8 inches); (12) gypsum tile partitions, 4 inches, plastered; (13) exterior walls constructed of 4-inch face brick ($60.00 per M) with 8-inch clay tile back-up, plastered; (14) aluminum windows, window sills, and roof edge; (15) slate stools; (16) corridor wall, clear-glazed structural tile, corridor 12 ft 0 inch wide; (17) glass block, 8 inches x 8 inches, directional; (18) windows, clear glass, double strength, "A" grade; (19) classrooms assumed built on level site, no grading included.

References

1. Boyd, R. A.: "The Attainment of Quality Daylighting in School Classrooms," ILLUMINATING ENGINEERING, Vol. XLVIII, No. 1 (January 1953).

2. See also studies by architects Kenneth C. Welch and H. G. Daverman, *Architectural Forum*, October 1953.

3. Logan, H. L., and Lange, A. W.: "The Evaluation of Visual Comfort Data," ILLUMINATING ENGINEERING, Vol. XLVII, No. 4 (April 1952).

DISCUSSION

J. W. GRIFFITH:* It is most unfortunate that the authors chose the title "Manufactured Light Versus Daylight for School Rooms." For several years we have been trying to approach school room lighting from the standpoint of manufactured light *and* daylight. To properly discuss this paper would require an additional paper presenting the daylighting side of such a controversy. This would only tend to re-establish the old feeling in many of the school board members and executives that classrooms that are to be used during daylight hours need not have artificial lighting and certainly would not further the cause of integrated lighting.

I realize that a cost analysis can be made to favor almost any type of design and that lowering the cubage does not greatly lower the cost of construction; however, this is the first cost comparison I have seen that actually shows a saving in construction costs by increasing the ceiling height. Type A classroom with a 10-foot ceiling has a higher base cost than type B with a 12-foot ceiling height.

One point not discussed in the comparison of classroom types is that with the lower level of daylighting in Type D, the poor spectral quality of the fluorescent lamps will be more noticeable than in the other classrooms where the daylight tends to wash out this discrepancy.

The authors point out that the artificial lighting produces considerable uniformity. Unfortunately, the average class is made up of students who do not necessarily all like the same level of illumination. In fact the variation of illumination level required for certain types of tasks may vary in individuals as much as ten to one or even higher as has been brought out by Guth and Eastman.[1] In other words, if you do not have asymmetric lighting, you are forcing everyone to work under the average condition. Where you have asymmetric lighting as in the case of many daylighting installations, the individuals have a choice of levels depending upon the location of the desks. It is quite true that the teacher may not let the student have a choice. However, it is not the duty of the illuminating engineer to enforce good teaching practice, but provide proper lighting installations.

It is just as improper to design a classroom without daylight as it would be to design a classroom for daytime use without artificial light. If schools are designed without daylighting, it is quite possible that a trend would develop toward a "Standard School" design. This might be economical in that it would save the cost of an architect's fee, but it would also stifle progress.

In conclusion I would like to re-emphasize the statement made by the authors: "People think a daylighted school is a good school." People (and we design schools for the people) will continue to think a daylighted school is a good unless we develop some propaganda scheme to suppress their desires.

1. Guth, S. K., and Eastman, E. E.: "Footcandles for the Forgotten Man," ILLUMINATING ENGINEERING, Vol. LI, No. 3 (March 1956).

*Southern Methodist University, Dallas, Texas.

E. M. STRONG:* I think it was Past President Howard Sharp who first drew attention in a major way to the inappropriateness of the use of the word "artificial" to describe light other than from the sun. Introduction of the word "manufactured" by the authors is to be welcomed as an effort in this direction. There is nothing artificial about light obtained from candles or lamps; whether they use combustibles or electricity their light is the real thing. Artificial light in properly definable as a sensation of light stimulated by a substitute for visible electromagnetic radiation. Examples are found in electric shock around the head, or the shock of being hit over the head so as to "see stars."

The term electric light has been suggested: it is shorter than "manufactured light" but eliminates combustible sources. I like the still shorter term, "lamp light" which seems to some of us to cover the intended meaning simply and accurately.

R. W. MCKINLEY:** The authors have made a thought-provoking presentation on a subject of wide interest. Their cost analysis assumption that the same bidding pattern will apply in the four examples is necessary, but it brings out relatively small differences which are, as stated, not complete reflections of the total cost relationships.

They have neglected, as is common practice today, to include a comparison of the warm weather comfort problem, despite full recognition that cold weather comfort is an important cost element. Though of less importance in Minneapolis than in the South, ventilation is necessary for comfort. Also, they have not credited the rooms with larger glass area with the solar heating "bonus" which they provide during the short daytime occupancy hours, which explain why office design is usually based on different criteria.

L. V. JAMES:† My remarks are prompted, in part, by an experience one February morning in a Chicago suburban schoolroom. It was a bleak day, trying to rain. The head of a north exposure window was about eight feet from the floor and an overhang extended out about four feet.

Looking out this window, from a student's chair facing it, a band of sky appeared between the overhang and a row of houses and trees on the other side of a large playground, which sky, despite the weather, had by actual measurement a brightness higher than that of a standard T12 fluorescent lamp. Projected to the glass, this sky constituted a band of brightness two feet wide at that point and as long as the window.

What do you think would have happened to me had I recommended an almost identical condition due to an installation of sixteen of these lamps, mounted side by side, at the low elevation and directly in front of many of the pupils and also extending the length of the room?

This experience has been in my mind as I review this challenging paper. It gives many important details in connection iwth the lighting of schoolrooms, but is based on an important premise of viewpoint. It is really because I am afraid the details may have obscured the viewpoint, for many of those who read the paper, that I presume to emphasize it.

We may remonstrate with an architect and school board that daylight as such is not kind. We may insist that sky

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†Illuminating Engineering Consultant, La Grange, Ill.

glare and snow glare as well as sun glare are of an order out of all reasonable proportion to what we require of those who provide the so-called manufactured lighting in the room. Also we may note that blinds and other devices intended to control this glare are frequently inadequate and often not used. The reply we receive is the very proper one that the windows are needed to bring the out-of-doors environment into the room, and all that this implies, in which case we subside and do our best to assure that the most effective controls possible are installed and used.

It is true that the windows perform the very important, if not completely necessary, function of letting vision out. But it is also true that better means than these windows are available for providing illumination in the room, without the danger of uncontrolled brightnesses, which means are today well developed and economically competitive. Why then not insist that the window areas be provided and designed for the important function noted, but not require of them that they also perform the lighting function which they do so poorly, from the side of the room and with poorly controlled brightnesses?

This is the viewpoint to which I referred and which has impressed me more than the application details in the paper, interesting and important though these details are. And I commend it to you for serious thought and use in conferences with school architects and school authorities.

Let us dare to be honest and frank, rendering unto Caesar the things that are Caesar's and advocate the windows for the functions they can perform so well, with adequate controls that can and will or must be used. But let us not acquiesce in the use of these openings for purposes for which other means can provide so much better.

L. E. JOHNSON and R. F. HAMMEL:* We appreciate the time the discussors took to comment on our presentation. These men have spent considerable time studying the problem of school lighting and their comments, either pro or con, do contribute to bringing the picture into clearer focus. Varying conditions and needs may never allow a simple black and white solution to the problem, but discussions like this should help to give proper emphasis to each of the elements we are working with. We agree with Mr. Griffith that this subject should have more time on a program. That is one of the major problems of a national conference — too much ground to cover and too little time to do it.

Regarding the title of the paper, we were not too happy with it either, but at the time could not think of a simpler one that would be descriptive.

Regarding cost studies, there were many factors that were considered and eliminated in the interest of simplicity before we reduced it to the three items shown. The items included seemed pertinent and factual. The construction cost figures were furnished by an estimator active in the school construction field, and it is actually true that using construction as listed, the saving in using smaller windows in Type B would more than compensate for the extra construction cost of interior partitions for the 12-foot ceiling. Hence, the lower cost figure for Type B over Type A in spite of the higher ceiling. There was only an $84 differential so for all practical purposes they could be considered comparable.

*Authors.

Regarding spectral quality, the authors were not aware that this was a factor in any areas except perhaps art rooms or where appearance of foods was critical.

There would seem to be merit in arranging students in a schoolroom so those who need it most could have the advantage of the higher illumination levels near windows, etc. We assume it is not practical, however, since we know of no schools that are doing this. It appears that the variation experienced in daylight levels in the room are not intentional but result rather from the nature of the source and the utilization techniques. If there were techniques which would make possible greater uniformity from daylight, with no penalties, we are sure they would be advocated.

Regarding the use of propaganda in promoting an idea, it is perhaps possible to momentarily influence school authorities and architects by its use, but the impact would not be for long and could actually retard an idea rather than advance it. We believe, too, that the commercial aspects of this picture must be minimized.

Regarding Mr. Griffith's concern of a standardized school design, we feel that lighting and visual environments are but two of many factors in school planning that an architect must consider and which require his professional services. Even if we consider lighting only, we know that there will be continual changes in light sources, equipment application and techniques, in addition to increased knowledge of the subject that will require his professional interpretation, skill and services.

In reply to Mr. McKinley's comments on cost figures, we do not think that cost will be the final determining factor in developing school designs. They were presented in this paper as stated "to indicate that operating cost need not be a deterrant to considering the designs relying exclusively on manufactured light for lighting levels." It may be interesting to note that in our estimates Type D construction was about 93 per cent of Type A construction. In a comprehensive cost study included in a report of the Department of Architecture at Pratt Institute,[1] construction comparable to Type D was about 83 per cent of that comparing with Type A. Had we used these figures the cost differential would have been far greater.

Regarding the "bonus" of solar heat gain, this is a very complicated subject and involves not only building materials but orientation of rooms, number of overcast days, type of heating or ventlating system, ability to "pipe" excessive solar heat from the warm portion of the building to the colder areas, control of windows, etc. We did not include this heat bonus nor did we include the penalty of excessive heat gain from solar radiation. Cost estimates of removing heat (per Btu) run several times that of adding heat — some estimates as high as 10 to 1. If these total costs are somewhat of the same magnitude for the school year, which we have assumed, they would cancel out and we would arrive at the figures shown.

We appreciate Mr. James' comments on the paper. We have wondered, too, why there should be a double standard for visual comfort between applied daylight and manufactured light. His reaction to the paper coincides very closely with our feeling on the matter.

1. "School Research Thesis," Bulletin No. 1, New York State Association of School Business Officials.

Some Methods for the Improvement of The Strength of Miniature Filament Lamps

By J. MARTIN

Change to 12-volt electrical systems in the automotive industry, and the use of 28-volt supplies in aircraft and heavy surface vehicles, have presented a challenge to the designer of miniature incandescent filament lamps.

Increased voltages have resulted in smaller diameter and longer length filament designs which consequently are weaker in their resistance to impact and vibration failure.

In this paper, the intent is not to present a complete solution to this problem, but rather to describe some of the practical methods that have been adopted to provide for the improvement in filament strength.

Mechanism of Filament Failure

Before discussing means to improve the strength of the lamp filament, the reasons for filament failure will be examined.

A miniature lamp filament is subjected to a series of impacts and shocks not only during its life, but especially at the time of installation and final testing of the product in which it is used. In addition, the lamp must withstand severe tests on a selection basis, which are devised by both the lamp and product manufacturer as an insurance for lamp quality.

For example, the vibration of an automobile motor, the impact caused by the slam of a trunk lid or glove compartment door and the shocks encountered by varying road conditions, are some of the forces which the filament must endure. During this time, the filament is either hot and ductile or cold and brittle. Fig. 1 illustrates the distortion in the coil of a 12-volt glove compartment lamp as produced by the impact of the closing door during approximately six months of use.

The test equipment, which is being used to duplicate the field conditions of the lamp, may be divided into three types.

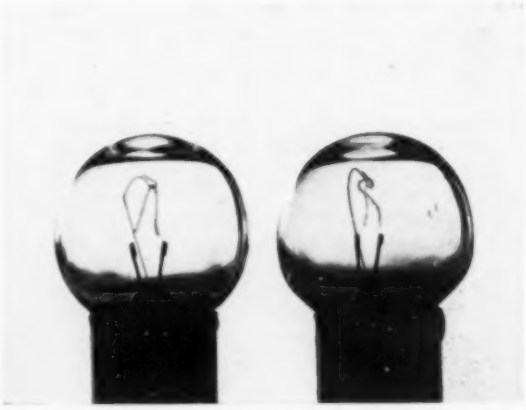

Figure 1. The lamp on the right is an example of the distortion in the coil of a 12-volt automotive glove compartment lamp after approximately six months of use. The lamp on the left has never been used.

1. Shaker tables — which seek out the resonant frequency of the lamp filament or its supporting structure. Since the resonant frequency will vary from lamp to lamp because of variables in lamp manufacture, this test is applicable in general, for only one lamp at a time. One type of shaker table is shown in Fig. 2.
2. Mild Impact Test — This provides for testing a large number of lamps simultaneously. The distribution of the energy in the resulting impact is sufficient to cause each filament to resonate at its own natural frequency. Fig. 3 shows a group of lamps mounted on a tester of this type. In Fig. 4 the motion of a lamp mounted on the impact tester frame and resulting vibration of the center turns of its coil have been plotted with the aid of high speed photography.[1] Note how the amplitude of the vibrating coil turns changes with the instantaneous velocity of the impact tester frame.
3. Hot Shock Test — This type of test is usually performed when the filament is burning at rated voltage or overvoltage and causes the

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 12-16, 1955, Cleveland, Ohio. AUTHOR: Westinghouse Electric Corp., Bloomfield, N. J.

Figure 2. (Left) This shaker table is used for determining the natural resonant frequency of lamp filaments or other elements of the lamp mount.

Figure 3. (Right) This impact tester excites the lamp filament many times per minute as the lamp-holding frame is raised and then lowered onto the steel anvil by the action of the step cam.

filament to deform rapidly as it is stressed beyond its elastic limit and continues to stretch out until the filament wire fractures. Fig. 5 illustrates a drop tester which provides for such a hot shock test. The test can be varied in severity by simply raising or lowering the height of the drop of the test plate which supports the lamps.

The stresses occurring in a filament when it is subjected to the above tests, are complex; and no attempt will be made to analyze these in detail here. Torsion, shear, and tensile stresses are certainly present. Also, the metallographic structure and thus the physical properties of the tungsten wire change with the burning time. There are, in addition, other effects such as the shorting of adjacent filament turns, or the whipping action of a filament support, either of which will accelerate lamp failure.

Methods of Attack

In this paper, three methods of attack are considered as a means for prolonging the life of a filament under conditions of impact and vibration. These are:

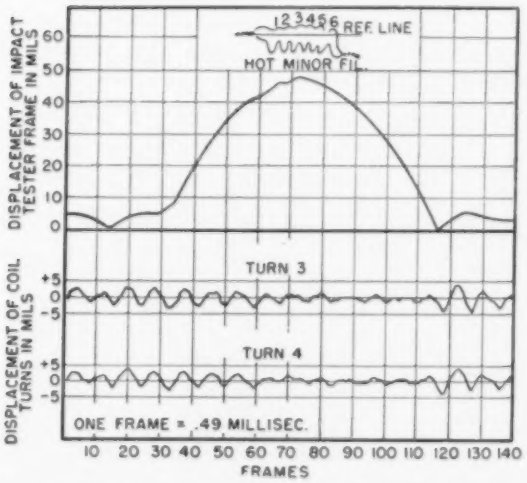

Figure 4. The upper curve is a plot of the displacement of a lamp on the impact tester shown in Fig. 2. The two lower curves show the change in amplitude of vibration of the two center turns of a filament as it is excited by the motion of the impact tester.

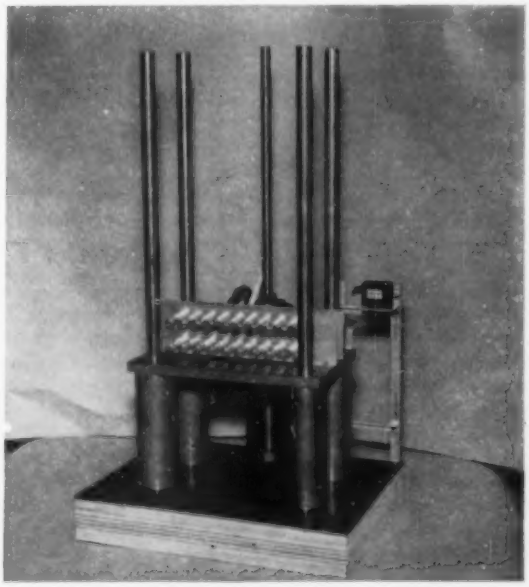

Figure 5. This drop tester subjects the lamp filaments to "hot shocks" as the lamp support plate is dropped onto the anvils. The severity of the test is varied by varying the height of the drop.

1. The use of a filament support of the proper shape and size.
2. The increase in the diameter of the filament wire by reducing its design efficiency.
3. The change in the crystal structure of the filament wire by metallurgical means.

Each method is discussed in some detail below.

Filament Support

Lamps which have filaments with long coiled sections generally are supported by a molybdenum anchor. The size and shape of the support will determine whether it will help provide strength to the filament or hasten its destruction. When properly designed, the resonant frequency of the anchor should be close to the natural resonance of the filament. This provides the filament with a "cushioned" support which will not tend to distort the moving filament. Since it is difficult to expect the anchor and filament to move in unison when vibrating, the loop of the anchor which drapes the filament should be designed so as to allow enough room for the free movement of the coil barrel. Fig. 6 shows the relation between the length of 0.005 inch and 0.0035 inch molybdenum support wire and its natural resonant frequency as determined empirically with a shaker table.

The filament anchor can also be used as a restraining support in instances where the filament is subjected to large forces perpendicular to the filament barrel. This was demonstrated in the design of a lamp to be used on the tip of a helicopter rotor. Forces at the rotor rip range between 750-1000 times gravity dependent upon the type of helicopter and the flying conditions. Forces of this magnitude were found to be more than the filament of a standard 12-volt lamp could withstand. By using two 6-volt filaments in series and supporting each filament barrel at its midpoint with a sturdy anchor, the filament was prevented from bowing

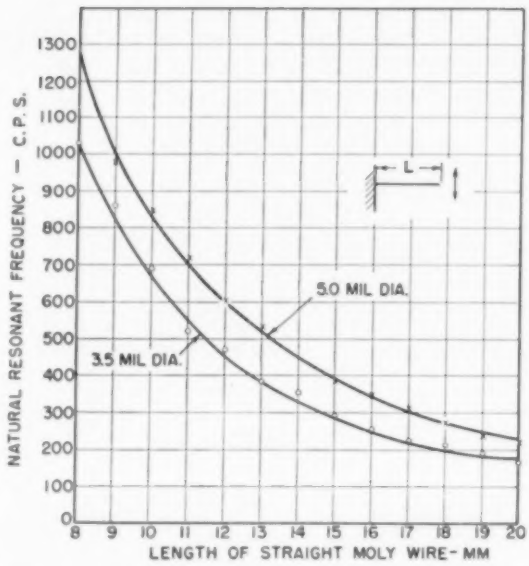

Figure 6. The relation between the length and the natural resonant frequency of straight molybdenum wire used for filament anchors.

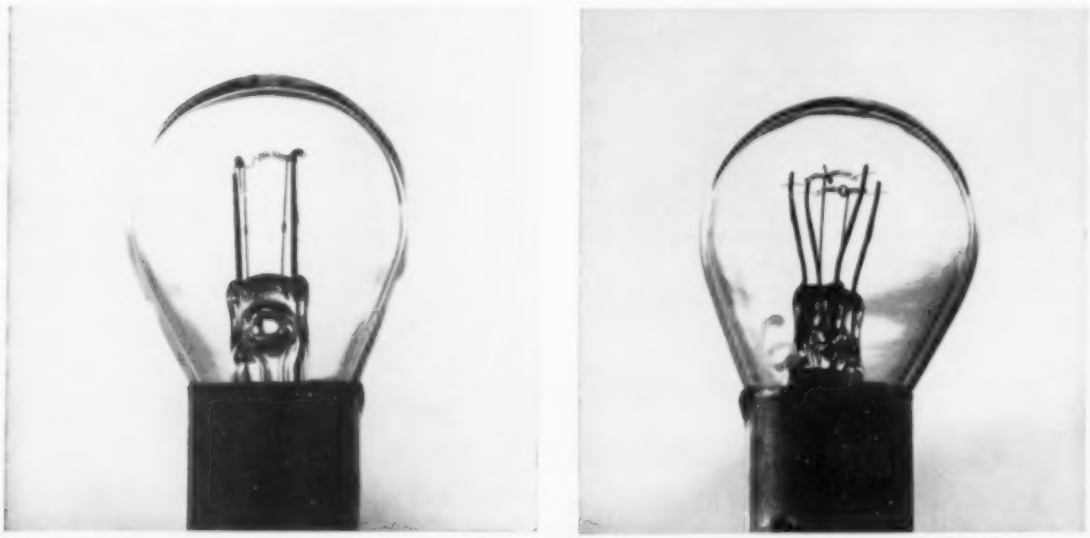

Figure 7. The properly supported filaments of the helicopter rotor tip lamp shown on the right resisted the force developed by 1000 g's for 150 hours; while the 3-sectional filament in the lamp on the left failed after 20 hours under the same test conditions.

and failing rapidly when subjected to flight conditions. The lamp on the left in Fig. 7 failed to withstand the rotor tip forces because of the long improperly supported coil barrel sections while the lamp on the right with each filament properly supported, had no difficult in resisting these high centrifugal forces.

Filament Wire Diameter

An improvement in filament strength has been obtained by increasing the filament wire diameter. This change can be made by shifting the design voltage slightly *e.g.* from 13.0-volt to 12.5-volt or by increasing the life of the lamp. In either case, there will be a decrease in the design efficiency of the lamp.

An increase in the wire diameter with a subsequent reduction in efficiency aids filament strength (1) by increasing the cross sectional area of the wire and (2) by lowering the operating temperature of the filament. The force required to fracture a filament is obviously greater if the cross sectional area is increased, and also, the modulus of torsion for tungsten wire decreases rather rapidly with an increase in temperature in the operating region for incandescent lamps.[2]

There are several limiting factors involved in changing the filament wire diameter. These are the size of the bulb, the candlepower maintenance and the life of the lamp. As the wire size is increased, the wattage will increase, and this will cause the bulb temperature to rise. In a gas filled lamp, this may cause blistering or bulging. Early blackening of the bulb walls due to the excess heat, will reduce the light output and shorten the effective life of the lamp. In addition, the increase in wire size may cause difficulty in coiling the filament and assembling the bulb to the mount because of space limitations in the bulb neck.

Another point to consider is that an increase in wire size will cause the mass of the filament to increase with a resultant decrease in the natural resonant frequency of the coil. This can be important, if certain critical frequencies are to be avoided.

Metallurgical Approach

The strength of a tungsten filament is intimately related to its metallographic structure. When first mounted in a lamp, the filament structure is, in general, fibrous and ductile, and possesses mechanical properties which should permit it to withstand rather severe treatment. The fibrous structure of a drawn tungsten filament is shown in Fig. 8. When lighted to incandescence, however, the long fibres of the drawn wire break up into crystals at a rate which is dependent upon the temperature of the filament. In a pure tungsten filament, these crystals grow as the lamp continues to burn until they occupy the full cross section of the wire. These grains are somewhat longer than the wire diameter and are divided by boundaries which in general run transverse to the axis of the wire.

When operated at normal temperatures, filaments with this type of structure tend to sag along these grain boundaries resulting in an open pitch and a deformed coil. Of course, under forces in excess of gravity such as encountered when the lamp is subjected to impact or shock this action is accelerated, and the filament fails prematurely.

Increased stability in the filament structure above the recrystallization temperature has been obtained by "doping" or the use of additives. The additives, depending on the type used, perform either of two functions when the recrystallization temperature is reached; (1) it restrains the growth of the tungsten grains or, (2) it causes enlarged or exaggerated grain growth. Smithells[3] has shown that approximately one per cent thoria causes the grain size of the doped wire after 1000 hours burning to be comparable in size to the grain size in a pure tungsten filament after one minute burning. The grain structure in a recrystallized thoria-doped filament is illustrated in Fig. 9.

Since the structure of the recrystallized thoria-doped wire consists of many small grain, the path through a cross section of the wire is no longer direct as in "undoped" wire, but irregular and considerably lengthened. By breaking up the grain boundaries in this fashion, slipping or the movement of the crystals along the grain boundaries as occurs in pure tungsten wire, is greatly resisted and the result is a wire which is more stable at elevated temperature, and which can more readily withstand shock and vibration.

Before attempting to use thoria-doped wire to improve the strength of the filament, there are several factors to consider. The operating temperatures of many miniature lamps are such that the thoria additive is slowly reduced to pure thorium by the tungsten. When this occurs, the grain growth is no longer restrained, and the filament sags excessively as in the case of a pure tungsten wire. Also, any phosphorous or sodium vapor which may be present in the lamp will reduce the thoria, and thereby create the same effect.

The second effect on the recrystallized filament structure, *i.e.*, exaggerated grain growth, is caused by adding various alkalis such as Na_2O and K_2O. These may be added to the raw tungsten powder in

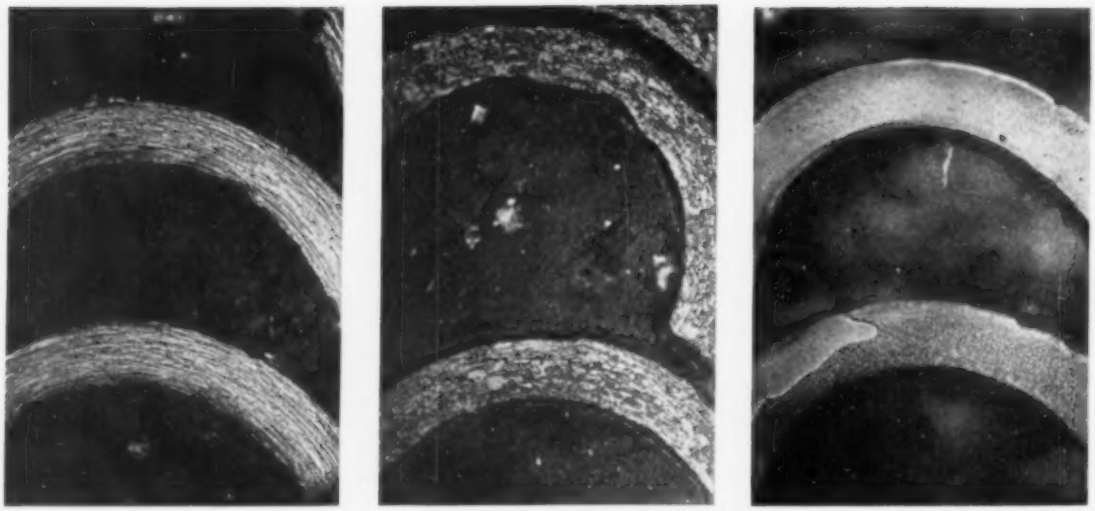

Figure 8. Coiled filament of tungsten showing the ductile fibrous structure before recrystallization occurs. (X700)
Figure 9. The recrystallized structure of a coiled tungsten filament containing less than 1% thoria. Note the small grain sizes and the irregular grain boundaries caused by the retarding effect of the thoria additive. (X700)
Figure 10. The recrystallized structure of a coiled filament containing a small amount of silica. The filament was "burned" for the same period of time as the filament in Fig. 9. Note the continuous crystal growth and the "long" longitudinal crystal boundary in the lower left of the photomicrograph. (X700)

combination with silica or thoria. Although many of these additives leave the tungsten during processing, the result is to produce, in the recrystallized structure of the lamp filament, grains which are many times longer than the wire diameter and in some instances approach the entire length of the coiled filament. The long grain boundaries in this structure tend to run longitudinally as compared with the transverse paths in a pure tungsten wire. This is illustrated in Fig. 10 which is a photomicrograph of several turns of a recrystallized silica-doped tungsten filament. Note the absence of small grains and the length and direction of the grain boundary. The direction of the grain boundaries and the size of the grain provide this wire with good non-sag properties, and increased ductility at room temperature after recrystallization. Lamps made with this type of wire resist filament failure due to impact and vibration fairly well.

The number, the combination, and the types of additives that can be mixed with tungsten powder of varying impurity are practically infinite. These additives plus variation in processing techniques may lead to the production of filaments with strength properties much better than anything presently in use.

Conclusion

The methods discussed above are just a few of the possibilities which have been explored for improving the strength of miniature lamp filaments. There are many others; for example, the configuration and mounting of the coiled filament are very important. Since motion of the filament cannot be completely eliminated when the lamp is vibrated or shocked, the next best thing is to control its deflection by providing means for rapid damping or by designing so that the natural resonance of the coil is well out of range of any critical frequencies that the lamp may encounter. A good guide for this is the well-known equation for the resonant frequency of a perfect string.[4]

$$fo = \frac{1}{2L}\sqrt{\frac{T}{m}}$$

where L = the unsupported length
T = the tension
m = the mass per unit length.

Of course, in designing for mechanical strength, the life, the efficiency, the power input, the space limitations, and other features of the lamp cannot be ignored. In many instances, depending on the application, some compromise must be made to provide for the necessary requirements of a particular light source.

The tungsten filament in use today, is far from lacking in strength. Considering the thermal shocks encountered and the operating temperatures of this device, it has quite a remarkable resistance to failure. For this, much credit goes to the metallurgist and chemist in their work with the

structure of the tungsten wire; and it is they who will undoubtedly help provide the greater strength required of lamp filaments as new applications of increasing severity are demanded.

We wish to acknowledge the assistance given in the preparation of this paper by Mr. Herman Ehringer, especially for Figs. 8, 9 and 10 and by many other engineers of the Westinghouse Lamp Division.

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DISCUSSION

L. E. BARBROW:* It is essentially axiomatic that any improvement in an article is desirable. Accordingly, this description of several means for attaining increased strength of miniature-lamp filaments will be welcomed by the lamp-using public and also by the automotive industry. The question that arises, however, is whether the end in view could be more economically, readily, or satisfactorily attained by another approach.

It would appear that much of the difficulty encountered with filament breakage arises from too rigid mounting of lamps. In the case of 240-volt lamps with their long, thin filaments, a great deal has been accomplished in the way of having the lamps meet rugged operating conditions by developing resilient sockets or fixture mounts which cushion the lamps and their filaments from shock. This has similarly been done with good effect with 120-volt lamps and should be even more effective with 12-volt lamps.

We are all pleased that lamp manufacturers are making strides in their efforts to make filaments more rugged but I hope that this will not result in having the automotive engineer feel released from his obligation to protect automotive lamps from excessive shock. Is the author familiar with what the automotive industry is doing along this line?

Shifting the design voltage from 13.0 to 12.5 volts is given as a means for increasing filament diameter and thus of obtaining increased filament strength. Since the lamps in service will operate at a voltage over which the lamp designer has no control, it would appear that lowering lamp design volts will result in lamp operation in many cases at higher than design volts with resultant higher filament temperature and lower filament strength. I would appreciate clarification of this point.

H. A. ANDERSON:** The author of this paper has presented some interesting methods for improving the strength and durability of low voltage miniature filament lamps.

In considering the best type of filament construction for vibration and shock conditions, it is sometimes advisable to wind the filament on a smaller mandrel in order to obtain a longer coil. This would make it practical to use an additional filament support wire. In general, this is the principle used in designing rough service and vibration lamps for regular voltage service. In other words, longer filaments are used for the same wattage so that additional support wires can be used.

The author also commented that a larger diameter tungsten wire could be used to strengthen the filament. However, this would result in a higher wattage and in some cases consequent bulb blistering and other troubles. This situation can be avoided by increasing the length of the tungsten wire in addition to the diameter so that the resistance would be the same. The current and wattage would now remain constant as well as the total heat in the bulb. However, the advantage of lower filament operating temperature would be obtained as well as the extra strength with a heavier wire. Also the filament would be longer thus possibly permitting an additional filament support wire, thus making for a generally stronger lamp construction.

Incidentally, there are many factors in the winding of tungsten filaments that can affect their performance, especially under conditions of severe vibration and shock. We naturally assume that the coil winding equipment and facilities are such that uniform high quality filaments are produced. However, there are many techniques in the winding of fine tungsten wire that are necessary to maintain the good ductility and strength the metallurgists have built into the wire itself. Examples of these would be correlation of bobbin speeds to the wire size as well as tension controls on both the tungsten wire and mandrel wires. Also, subsequent hydrogen annealing operations must be carefully controlled since the slightest stretching of the coiling on the mandrel in these steps can be a cause of subsequent brittleness and non-uniformity.

These factors are mentioned for consideration since no detail of lamp manufacture can be overstressed in the type lamps under discussion.

E. H. RADDIN:* The author was confronted with the problem of maintaining the filament strength when the lamp voltage was increased from 6 to 12 volts.

The lamp engineer always has the problem of designing the filament and filament mounting of incandescent filament lamps, to produce the maximum filament strength. The author has shown, in this paper, his success with his particular problem.

It would seem that the very small difference in the size of the tungsten filament necessary to change the voltage from 13.0 volts to 12.5, would make very little difference in the lamp wattage and the bulb temperature and was not the important factor in this particular problem.

Curves in Fig. 6 showing the relation between the length and the natural resonant frequency of 3.5 and 5.0 mil molybdenum wire should be very helpful to the lamp designer. Also, it would be helpful if it included more wire sizes, covered tungsten supports and lead wires.

I would like to inquire if the author has made such tests and with what results.

JACK MARTIN:** We wish to thank the discussors for their comments. They have aided greatly in clarifying this paper.

Mr. Barbrow suggests that the automotive engineer should assume part of the responsibility of protecting lamps from

*National Bureau of Standards, Washington, D. C.
**Chief Engineer, Duro-Test Corp., North Bergen, N. J.

*Champion Lamp Works, Lynn, Mass.
**Author.

excessive shock. On this we heartily agree. However, we are certain that the automotive engineer is aware of the lamp strength problem. His solution must be consistent with low cost, available space, and the requirements of the stylists.

An example of the changes that are being made by the automotive designer to improve lamp strength is the case of the glove compartment lamp whose socket was an integral part of the on-off switch. This arrangement was not the best and caused early lamp failure due to the shock of closing the compartment door. The problem was solved simply by separating the lamp socket from the switch. Another instance is a change in a tail-light assembly which is raised to gain access to the gasoline tank filler pipe. Here, relocating the lamp socket with respect to the tail-light cover reduced the shock to the lamp and improved lamp life. On ordinance type vehicles where styling and space limitations are less restrictive a great deal has been done with shock mountings.

In reference to Mr. Barbrow's question regarding the shift in design volts from 13.0 to 12.5, it should be noted that this change was also accompanied by an increase in life and a change in voltage for design life, *i.e.* the voltage for design life was raised to 14.0. This enables the lamp to have the proper light output at the average socket voltage and also prevents reduced lamp life as the voltage at the socket increases above this average value. These changes resulted in an increase in wire diameter without an increase in filament temperature.

Mr. Anderson has offered several good points for filament strength improvement. The suggestion to make the filament longer and adding supports has its limitation. For example, to a miniature lamp designer a 12v coil means high voltage and a coil design approximately twice the length of its 6v counterpart. This coil and its supports must pass through the same bulb neck opening with the same ease and speed as did the low voltage filament. Any increase in strength that might be obtained by an increase in length and the number of supports would be offset by the resulting manufacturing problems. Also, a lengthy coil with additional supports creates the problem of maintaining a sufficient amount of clearance between the hot filament and inner bulb wall.

It is agreed that great care must be exercised and all factors considered during coil winding and the subsequent treatment of the coiled filament wire. Here again, we would like to point out that in miniature lamp manufacturing, in many instances, the coils are wound and immediately mounted on the lamp stem. This makes treatment of the filament after coil winding impractical.

We agree with Mr. Raddin that a change in filament design volts from 13.0 to 12.5 will be insignificant so far as an increase in filament wire size is concerned. However, this change coupled with a reduction in efficiency by changing lamp life will allow for a significant increase in wire diameter. Admittedly, the paper states this effect is obtained by changing either design volts or life. In the situation referred to, the change in design volts and the increase in design life (30 per cent) permitted an increase in wire diameter of 23 per cent with a resultant improvement in strength on the tester shown in Fig. 3 of approximately 20 per cent (based on the area under the lamp mortality curves) and 75 per cent (based on the number of lamps remaining operative at the completion of the test). The increase in wattage, however, caused a drop in light maintenance of 15 per cent which offset the gain in strength. This was pointed out as being one of the pitfalls in gaining strength by increasing filament wire size.

With regard to Mr. Raddin's question on the curves in Fig. 6, these are the only tests which have been completed. We are considering further work on different sizes and materials.

Warsaw Today

A night view of Warsaw, Poland, from Castle Square looking toward Krakowskie Przedmiescie Street. In the foreground is the King Zygmunt Column, an ancient Warsaw landmark. Note ornamental lantern type street lighting units (unit at lower right, beside bus, not turned on) at relatively low mounting height. Photo from: The Polish Embassy, Washington, D. C.

INSTALLATION AT STAKS RESTAURANT, 5223 WEST CENTURY BLVD., LOS ANGELES, CALIF.

Exterior Lighting of a Restaurant

LIGHTING OBJECTIVE: To attract attention to the location of the restaurant and to create interest by dramatizing the beauty of the building exterior and landscaping.

GENERAL INFORMATION: This restaurant specializes in charcoal-broiled meats and special hamburgers, and is located on a dark street next to a well-lighted service station. The exterior is redwood (15% RF) and fieldstone (45% RF). The architectural canopy on the front of the restaurant projects outward 4 feet; along the side of the building which is adjacent to the parking lot driveway, the canopy projects outward 3 feet.

The pole on which the sign is mounted is an 8-inch I-beam painted white. The sign, mounting height 20 feet, is made up of acrylic plastic disks with metal letters projecting 2½ inches beyond the face of the plastic. The dimensions of the letters are: height 30 inches, width 20 inches, and stroke 4 to 7 inches.

Both disks and letters are in color as follows:

	Plexiglas	Letter
S	dark green	white
T	orange	dark blue
A	white	black
K	blue	yellow
S	yellow	green

(over)

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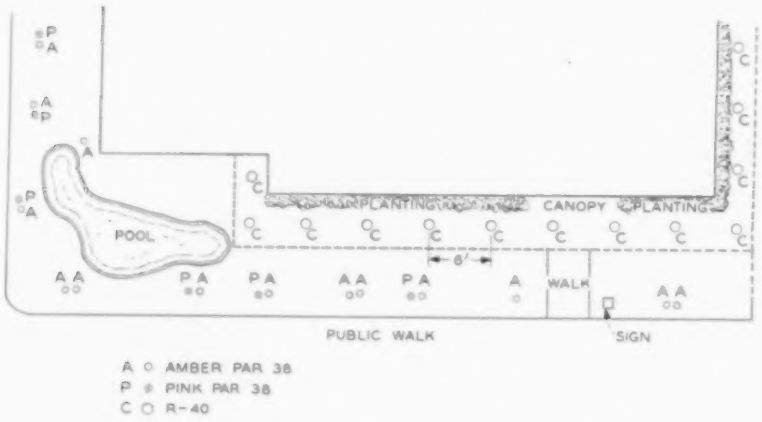

Figure 2. Plan view of exterior of restaurant.

INSTALLATION: The blank wall and shrubbery are floodlighted in color by twenty-three cast metal holders (Metalcast Products, Inc., "Moldcast" M-150 Green), using amber and pink 150-watt PAR-38 lamps with integral color filter (Luxor Lighting Products, Inc). The distribution and color of the units are shown in Fig. 2. Brightnesses are as follows:

redwood	6 ft-L min.	15 ft-L max.	10 ft-L avg.
fieldstone	8 ft-L min.	18 ft-L max.	12 ft-L avg.

The canopy contains eighteen downlights (Marvin Mfg. Co., "Marco" J 320) using 150-watt R-40 lamps on 6-foot centers. The average illumination under the front canopy at the entrance is 24 footcandles.

The illuminated pole employs 4500K white 15 mm single cold cathode tubing (Sylvania) operated on a 60 milliampere transformer. The tubing is recessed in the cavity in both sides of the I-beam, and the channels are covered with hardware cloth for protection.

The sign is illuminated from behind the plastic with 4500K white 15 mm cold cathode tubing on 4-inch centers. The brightness is 5 footlamberts minimum and 27 footlamberts maximum at a 30-degree angle of observation. Visibility distance is 0.4 mile.

Lighting designed by Harold I. Strahn, Illuminating Consultant, Department of Water and Power, City of Los Angeles, Calif.; restaurant was designed by the principal partner, S. M. Schwartz; installation made by the Field Industrial Electric Co., 2106 West Slauson, Los Angeles, Calif.; sign was fabricated (from owner's idea) by the Heath Co., 812 North Broadway, Los Angeles, Calif.

Lighting data submitted by Don Romanoff, The Ruby Lighting Corp., 1212 South Olive St., Los Angeles, Calif., as an illustration of good lighting practice and to aid in the design of similar installations.

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Effect of Operating Variables on Mercury Lamp Performance

By E. B. NOEL
E. C. MARTT

THE PERFORMANCE of mercury lamps is affected not only by the lamp design, but also by the design of the ballasts that operate them. There are several types of mercury lamp ballasts on the market today, and each type operates lamps in a different manner. Considerable data have been published on lamp operation with the common lag ballast, showing how it changes with variations of primary voltage and to what degree the initial lumen output is lower in horizontal burning.[1] However, there has been no similar information published as to how these newer types of ballasts affect lamps under like conditions. Some of the newer designs have excellent operating characteristics in some respects, while in other ways they can be harmful to the lamps. For example, some ballasts have highly peaked current wave shapes. The problem of current wave shape has been thoroughly studied in the fluorescent lamp field, but there are no published figures as to the effect of wave shape on performance of high pressure mercury lamps. Another problem relating to ballast design has been in obtaining rated lumen output for horizontal burning. It is well known that the initial lumens are lower if the lamp is measured in a horizontal burning position on lag ballasts, in some cases six to seven per cent, but there are other ballasts that cause even lower output horizontally. How much lower depends on the ballast type. When the lamp wattage is increased in order to obtain the same lumens as in vertical burning, then excessive lamp current is necessary in some cases. If this high current is combined with poor wave shape, then early blackening of the arc tube will result.

For the sake of simplicity, only one size of mercury lamp is considered in this paper — the 400-watt series having quartz arc tubes. These lamps are of increasing importance in the general lighting field, and their operation is fairly typical of other quartz lamps of different wattages used for lighting. While these lamps are available in either hard or soft glass outer jackets, or may be had with or without color improvement, or in reflector bulbs, all of these variations have the same arc tube design. For this reason, the data in this paper apply to all of the 400-wat quartz mercury lamps.

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There Are Four Main Types of Mercury Lamp Ballasts

The circuits[2] for operating mercury lamps can be divided into four classifications: lag, lead, series, and constant wattage. These circuits all have the following primary functions: First, they must supply enough open circuit voltage to strike the arc initially. This voltage will depend considerably upon the ambient temperature of the lamp, increasing as the temperature decreases. Second, they must provide enough voltage to restrike the arc during each half cycle of operation and to maintain the arc for a large proportion of the half cycle. In order to meet this requirement, the open circuit voltage should be approximately 1.6 times the arc voltage for indoor applications. This value also includes a safety factor for stability so that lamps will not extinguish on a momentary line drop of about 15 per cent. Third, they must limit the arc current to the value set by the design of the lamp. For the 400-watt lamps, for indoor operation, the open circuit voltage is in the order of 220 to 230 volts; the arc has a nominal voltage of 135 volts and the operating current is 3.2 amperes.

Each of the four types of ballasts is made up of a different arrangement of components and has its own distinctive operating characteristics. Schematic diagrams for the four types are given in Fig. 1. These are not the only possible circuits for these lamps. Each of these types has its own numerous variations, or there may be an entirely different arrangement of components that accomplish the same thing. The circuits drawn correspond to the types for which results are given in this paper.

A. Lag Ballast

The inductive type ballast in its simplest form is a reactor or choke in series with the lamp. This

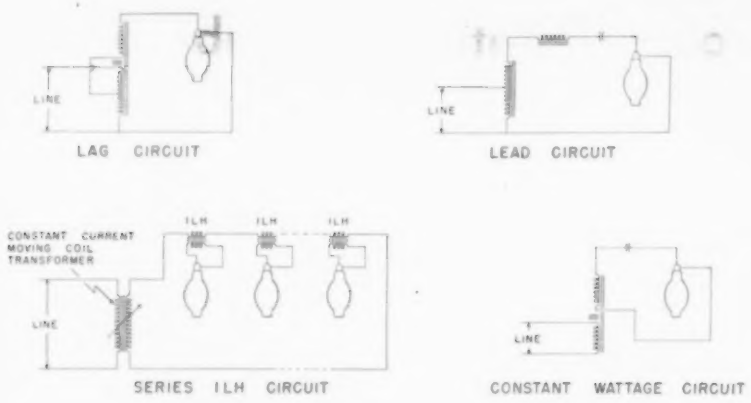

Figure 1. Schematic diagrams for typical circuits of lag, lead, series, and constant wattage ballasts for mercury lamps.

form of control, which is commonly referred to as a lag ballast, can be used where the supply voltages are high enough for positive starting and stable operation. In other cases where the supply voltages are lower than the required open circuit voltage, a step-up high reactive transformer or autotransformer may conveniently be used to limit the current. This latter type is represented in Fig. 1.

B. Lead Ballast

The lead circuit which is commonly encountered as part of a two-lamp ballasting circuit consists of an inductor and a capacitor in series with the lamp. An autotransformer can be used to obtain a suitable open circuit voltage. Since the capacitive reactance is higher than the inductive reactance, this ballast produces a leading load on the line. As will be seen later, the lead circuit has better lamp current regulation with respect to line voltage and lamp voltage variations than does the lag circuit.

C. Series Ballast

The series ballast, known for mercury lamps as the ILH transformer, is used for street lighting. In this circuit a large number of isolating transformers are operated in series from a constant current transformer. These transformers insulate the lamps from the high voltage on the supply line, and they also furnish the required open circuit voltage for the lamps. Since the current to the transformer primary is limited, the lamp current is limited also. These transformers have an air gap in the magnetic field which permits series primary current to flow in case of lamp outage.

There is a newer type of series circuit[3] rather recently on the market called a straight series circuit. In this type of operation the lamps are burned in a series string without the use of individual ballasts. The current is limited by either a moving coil constant current transformer or by a static type. These transformers also supply enough open circuit voltage to operate the entire string of lamps.

Data in this report taken on series circuits are from ILH transformers only, since this is the most common series circuit in operation today. Our measurements show, however, that there is a difference of only one per cent, or less, between readings on the two types, and so the same data apply to both.

D. Constant Wattage Ballast

This ballast is increasing in popularity in the mercury lamp field. It can have several variations in design, but basically it uses a capacitor and a reactive transformer with a portion of the core saturated to maintain a nearly constant lamp current for wide changes in primary voltage. Since lamp wattage will be constant if the current does not change, this ballast will hold the watts constant as the primary voltage changes, hence its name. As will be seen, however, the wattage differs from lamp to lamp depending upon the lamp voltage. In this respect it is not constant wattage, and this variation can have a considerable effect on lumen output. It has been previously shown that changes in the wattage loading of an arc tube affect lumen maintenance.[1] It is a very simple ballast to install and operate, however, since there are no voltage taps to select.

Variations in Line Volts Affect Lamps Differently Depending Upon Ballast Type

A user of mercury lamps is often aware that the line voltage to mercury lamp ballasts may vary considerably during the burning period. He is probably not so well informed, however, as to how this variation affects lamp operation, nor is he likely to be aware that the effect is different with the different kinds of ballasting circuits. For each

type of ballast we have varied the supply voltage and recorded the manner in which the lamp operation is affected. A total of six center-voltage H400-E1 lamps were used in these tests. These results are plotted in Fig. 2 for both vertical and horizontal lamp operation. These data are given on a percentage basis only, and the absolute values will be compared later in this paper. The discussion below is arranged according to ballast type.

On Lag Ballasts, Changes in Line Voltage Affect Lamp Performance Greatly

The graphs showing how line voltage affects lamps lamps on lag ballasts are given in Fig. 2 for both vertical and horizontal lamp operation. As can be seen from these curves, lamp operation is considerably affected by changes in primary voltage on these ballasts. A 10 per cent change in primary voltage, for example, can change lamp amperes about 20 per cent, watts 22 per cent and lumens 26 per cent for vertical operation. For horizontal operation these values are only slightly different for the same 10 per cent change in primary voltage. The corresponding change in lamp voltage in each case is small, about one and one-half per cent. The above figures clearly illustrate how widely the lumen and electrical values of lamps can vary with varying supply voltage on lag ballasts. Because of this, lamps become overheated when they are burning in hot fixtures in conjunction with high supply voltage. Shorter lamp life and poorer lumen maintenance than normal commonly occur in such cases. It is important, when using lag ballasts, to be certain that the proper voltage tap is being used and that the supply voltage is not consistently much higher than normal. In cases where supply voltage is considerably lower than normal, no harm will result to the lamps, but lumen output will be less than desired.

On Lead Ballasts, Changes in Line Voltage Affect Lamp Performance Moderately

The graphs showing how line voltage affects lamps on lead ballasts are also given in Fig. 2 and labeled "Lead Ballast" for both vertical and horizontal operation. For this ballast, the same types of change occur with changing line voltage as with the lag, but in lesser amount. In this respect, the lead ballast has in some degree the properties of the constant wattage ballast. For vertical lamp operation a 10 per cent change in primary voltage causes about a 10 per cent change in lamp amperes, 11 per cent in lamp watts and 16 per cent in lumens. The corresponding figures for horizontal burning are 9 per cent, 10 per cent and 13 per cent. These figures are not nearly as high as were noted for the lag ballast, and for this reason there is not as much danger of overheating the lamps in cases

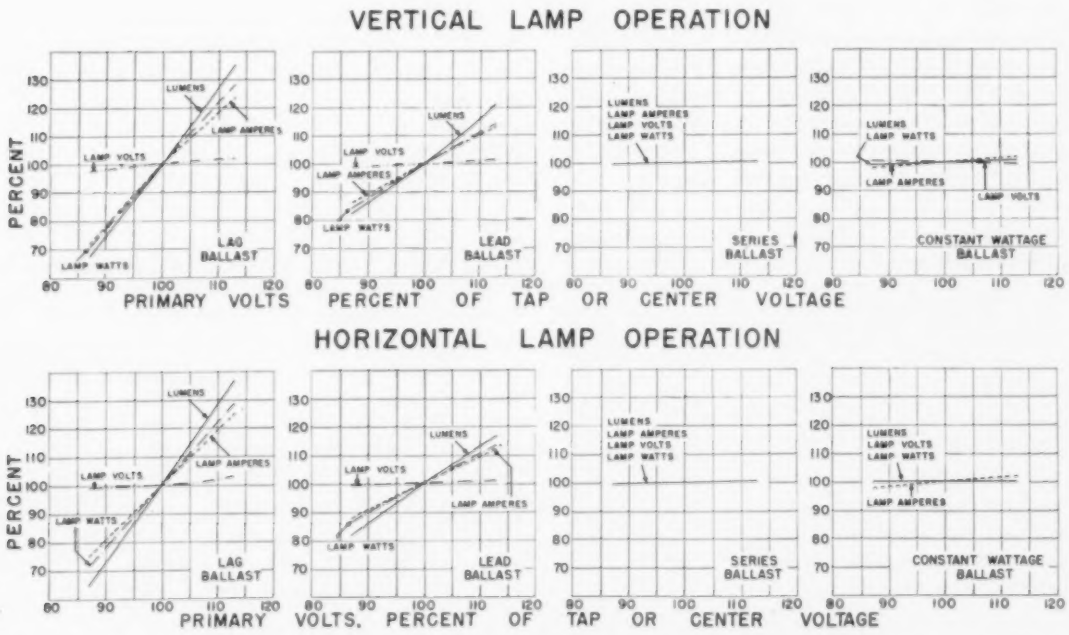

Figure 2. Change in 400-watt quartz mercury lamp performance with change in primary voltage for vertical and horizontal lamp operation on lag, lead, series, and constant wattage ballasts.

of high primary voltage, nor do the lumens drop as much where the primary voltage is low.

On Series Ballasts, Changes in Line Voltage Have Little Effect on Lamp Performance

The graphs showing how line voltage affects lamps on the series circuit are given in Fig. 2, "Series Ballast," for both vertical and horizontal lamp operation. As can be seen from the curves, line voltage has no appreciable effect on this circuit. The reason for this, of course, is that the moving coil constant current transformer which supplies power to the ballast primaries is unaffected by changes in primary voltage within the region measured. The circuit is affected by different lamp voltages, as will be discussed later.

On Constant Wattage Ballasts, Changes in Line Voltage Have Little Effect on Lamp Performance

The curves showing how line voltage affects lamps on constant wattage ballasts are given in Fig. 2 "Constant Wattage Ballasts" for both vertical and horizontal lamp operation. These curves illustrate why constant wattage ballasts are used for mercury lamps where supply voltage may change considerably during the operating period. For a ten per cent change in primary voltage, the watts and lumens change only about one-half per cent, regardless of burning position. In this respect these ballasts give excellent performance. However, as with series ballasts, they do not have nearly such good regulation with respect to variations in lamp voltage. Also, some designs may have a peaked current wave shape that causes faster lumen depreciation than is normal. These conditions will be discussed later in this paper.

Variations in Lamp Voltage Affect Operation On Some Ballast Types

There are manufacturing tolerances in the voltage of mercury lamps as in any other product. However, users of mercury lamps generally do not measure lamp voltages and are usually unaware of the effect that hese variations have on lamp lumens and operation on different types of ballasts. Lamps in the 400-watt series having quartz arc tubes have a voltage range of 120 volts to 150 volts due to necessary manufacturing tolerances. These voltages are measured with the arc tubes in a vertical position using a lag ballast.

The amount of mercury to be used for each lamp is found from curves relating the arc tube volume and arc gap to mercury quantity. By this method the voltages of a majority of the lamps can be controlled within plus or minus a few volts. However, there are several indeterminant variations that also affect the voltage. For instance, slight differences in the exact size and shape of the arc chamber ends may have an effect of several volts even though other measurements are the same. Also, the voltage of a mercury lamp is never exactly the same from start to start, and it may even change several volts during lamp life. For these reasons, it is necessary to have a voltage tolerance range of plus or minus 15 volts on a center of 135 volts.

On lag ballasts it makes very little difference how lamp voltage varies, since on this ballast, lamp watts and lumens are nearly independent of lamp voltage. On the newer types of ballasts, and on the lead ballast, however, this is not the case, and lamps on the high side of the normal lamp voltage range are subjected to more than nominal wattage. In Fig. 3 we have shown how lamp characteristics vary with changes in lamp voltage for vertical and horizontal lamp operation on the different types of ballasts. A total of 12 H400-E1 lamps were used in these tests. These graphs are discussed in detail below. The line voltage was held constant for all ballasts for this data. As can be seen from Fig. 3, the curves for horizontal operation do not cross the 100 per cent line at the center lamp voltage of 135 volts. The reason for this is that when lamps are changed from a vertical to a horizontal position the lamp voltage usually decreases. We have found that the voltage decreases an average of three volts to seven volts, depending upon the ballast type.

On Lag Ballasts, Lamp Voltage Affects Lamp Performance Very Little

It can be seen from Fig. 3, "Lag Ballast," for both vertical and horizontal lamp operation that the lamp watts and lumens are practically unchanged throughout the entire voltage range of the lamps. This is not true of lamp current, however. For vertical operation, the lamp current changes about 8 per cent for a 10-volt change in lamp voltage, while the lumens and watts are nearly unaffected. For horizontal burning the amperes change about the same as for vertical operation, the watts again are nearly unaffected while the lumens change about one per cent for a 10-volt change in lamp voltage. With respect to watts and lumens, the lag ballast is nearly unaffected by changes in lamp voltage, and this operation is comparable to the constant wattage ballasts in its response to changes in primary voltage.

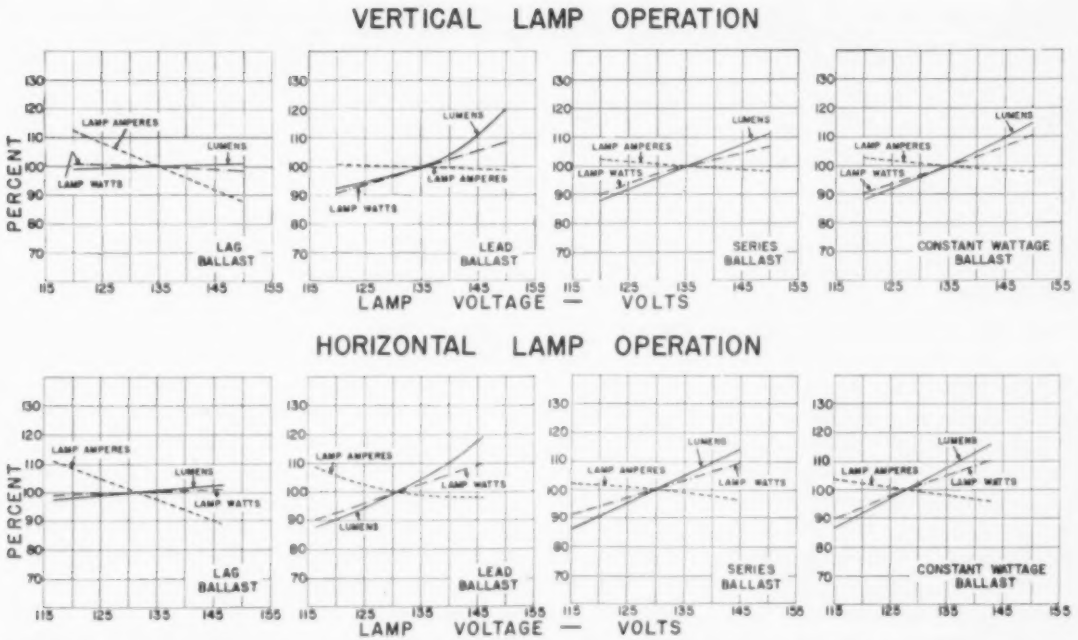

Figure 3. Change in 400-watt quartz mercury lamp performance for different lamp voltages for vertical and horizontal lamp operation on lag, lead, series, and constant wattage ballasts.

On Lead Ballasts, Lamp Voltage Affects Lamp Performance Considerably

The variations of lamp lumens, watts and amperes caused by variations in lamp voltage for lead ballasts are shown in Fig. 3, "Lead Ballast." They indicate that lamp lumens, watts and amperes are considerably affected by changes in lamp volts. For vertical operation, the lamp current decreases only 1 per cent for a 10-volt increase in lamp voltage. The watts, on the other hand, increase roughly five per cent while the lumens increase up to 10 per sent. For horizontal operation the results are about the same. Except for changes in lamp current, these values are considerably greater than that of the lag ballast under the same conditions.

On Series Ballasts, Lamp Voltage Affects Lamp Performance Moderately

Curves showing how lamps operate on series ballasts for different lamp voltages are shown in Fig. 3, "Series Ballast" for both vertical and horizontal operation. In both types of operation, the current decreases two per cent or less for a 10-volt increase in lamp voltage. Over the same change in lamp voltage the watts increase about five per cent, the lumens about eight per cent for vertical burning. For horizontal burning, the watts increase about six per cent, the lumens about 10 per cent over the same range. These changes are similar to those of the lead circuit.

On Constant Wattage Ballasts, Lamp Voltage Affects Lamp Performance Moderately

The effect of lamp voltage on lamp operation on constant wattage ballasts is shown in Fig. 3, "Constant Wattage Ballasts" for vertical and horizontal operation. From these curves it is evident that these ballasts are not constant wattage at all with respect to lamp voltage, hence the term "constant wattage" is not actually correct. For vertical operation, the lamp wattage changes about eight per cent for a 10-volt change in lamp voltage, while the lumens change about 10 per cent under the same conditions. The lamp current changes only slightly, about two per cent. The corresponding changes for horizontal operation are nearly the same in value. Lamp voltage for horizontal operation, however, has dropped about seven volts, the largest change for any ballast.

Horizontal Burning May Greatly Reduce Lumen Output

The curves in Figs. 2 and 3 that were discussed in detail above were all based on percentage figures, the output of each type of ballast being called 100 per cent. However, the absolute value of lamp

TABLE I — Comparison of lumen output and electrical values for the H400-E1 mercury lamp for both vertical and horizontal burning on various ballasts. Line voltage held constant.

Ballast	Lumens	Lamp Watts	Lamp Volts	Lamp Amps	Lumens Per Watt	Lamp Power Factor	% Lumens	% Watts	% Volts	% Amp
VERTICAL BURNING										
Lag	20,000	400	136.0	3.20	50.0	92.6	100	100	100	100
Lead	20,100	400	136.5	3.28	50.2	90.0	100.4	100	100.3	102.5
Series	20,200	400	137	3.18	50.5	91.8	101	100	100.8	99.4
Constant Wattage†	20,000	400	133.3	3.36	50.0	88.2	100	100	98.0	105
HORIZONTAL BURNING										
Lag	18,700	392	131.6	3.26	47.7	91.4	93.5	98.0	96.7	102
Lead	17,900	384	131.7	3.34	46.6	87.2	89.5	96.0	96.8	104.4
Series	18,000	379	131.4	3.24	47.5	89.0	90.0	94.8	96.7	101.3
Constant Wattage†	17,200	373	133.5	3.33	46.1	83.9	86.0	93.3	98.2	104

†A type having a high current crest factor.

lumens, watts, volts and amperes varies considerably with ballast type for horizontal operation in particular. In Table I the various types of ballasts are compared with respect to the absolute value of output. For vertical operation the differences are mostly very small. The only large departure is in the low lamp power factor of 88.2 per cent for the high crest factor constant wattage ballast compared to 92.6 per cent for the lag ballast. This low power factor results in a five per cent increase in lamp current to obtain lamp watts.

When lamps are burned horizontally rather than vertically, large changes take place. The lumens, watts and volts decrease and the amperes increase. Lamp power factor also decreases. The lumens on the lag circuit decrease 6.5 per cent while the drop is 14 per cent for the constant wattage circuit. This means that a lamp rated at 20,000 lumens in a vertical position will only give 18,700 lumens in the horizontal position for a lag circuit, 17,900 for the lead, 18,000 for the series and 17,200 for the constant wattage. Lamps are rated in the vertical position because the arc is more stable vertically and readings can be repeated more closely. It has been only within the past few years that horizontal operation has become widespread in street lighting, and in such cases it is important to know how the lumens decrease with horizontal burning.

It is reasonable to ask why the lumens decrease in horizontal burning of mercury lamps. One of the causes of this decrease is due to the fact that the arc floats above the arc tube axis when the lamp is in a horizontal position. This brings the hot, ionized gas closer to the relatively cold arc tube wall, causing it to de-ionize more rapidly during each half cycle. Faster deionization causes the current wave to be more peaked, and this in turn decreases lamp power factor and lamp watts. As a result, the lumen output decreases.

If the ballast itself produces a peaked current wave shape, then the lumens and watts will be decreased still further. This effect is evident in the data for the high crest factor constant wattage ballast which has a lamp power factor of only 83.9 per cent for horizontal operation. The output for this ballast is only 17,200 lumens and 373 watts, while for comparison, the lag ballast has a lamp power factor of 91.4 per cent, while the watts read 392 and the lumens 18,700.

Wattage to Obtain 20,000 Lumens Horizontally

There are now ballasts on the market that are made to operate the 400-watt quartz mercury lamp at 412 watts in attempting to obtain the 20,000 initial lumen rating in a horizontal burning position. In order to obtain the additional wattage, the lamp current must be increased, as can be seen from Table II. The required increase varies from six per cent for the lag to fifteen per cent for the constant wattage. If these higher currents are coupled with a poor wave form, as occurs with some designs of the constant wattage ballast, the

TABLE II — Lamp current to obtain various wattages for horizontal burning, and lamp wattts to obtain 20,000 lumens horizontally for the H400-E1 lamp.

Ballast	Amps for 400 watts Vertical		Amps for 400 watts Horizontal		Amps for 412 watts Horizontal		Watts to Obtain 20,000 Lumens Horizontally†
	Amps	%	Amps	%	Amps	%	
Lag	3.20	100	3.31	103.5	3.39	106	414
Lead	3.28	102.5	3.38	105.5	3.57	111.8	418
Series	3.20	100	3.46*	108	3.56*	111.3	413††
Constant Wattage**	3.36	105	3.57*	112	3.68*	115	425††

††On the basis that a 7.5% increase in watts means a 10% increase in lumens.
**A type having a high current factor.
*These figures are not taken from measurements, but are increased in direct proportion to the required wattage.
†Assuming lamps have 20,000 lumens vertically.

electrodes will be overheated, with the result that the arc tube will blacken faster than normally. A center ballast design wattage of 412 watts is only slightly above the lamp design center, and no trouble should be expected due to this slight overload alone, particularly with a lag type ballast. However, as has been shown earlier in this paper, on circuits other than the lag type, individual lamp voltage tolerances can push the lamp wattage up as much as 40 watts. Lumen maintenance can be expected to be poorer if the watts per square inch loading on the quartz arc tube is increased materially.[1] If the increased wattage is accompanied by very high lamp currents due to poor ballast wave form, then poor maintenance is certain to occur.

Referring to the last column in Table II, it is evident that, for lamps reading 20,000 lumens in a vertical position, more than 412 watts are needed to obtain equal lumens horizontally. The amount of increase necessary depends upon the ballast used. The reason that ballasts are being made to operate lamps at 412 watts horizontally is that lamps actually have average initial readings higher than 20,000 lumens. This means that it is not necessary to have more than about 412 watts to obtain 20,000 lumens in a horizontal position.

Some Types of Ballasts Have Poor Current Wave Form

One of the important variables of lamp operation that we have not discussed is the wave shape of the lamp current. We have found that poor current wave shape is damaging to lamp electrodes. This wave shape differs widely depending upon the type of ballast used. Furthermore, the wave is often more peaked immediately after lamp starting and during warmup than it is during normal burning. During the warmup period after starting, the pressure in the arc tube is low and the evaporation from the electrode is much greater than when the lamp is warmed up and full pressure has been developed. If the current wave form is badly peaked, both the increased r.m.s. value of current and the high peak value greatly increase the blackening created during the sensitive low-pressure period.

Oscillograms of lamp current wave form during warmup and normal burning are shown in Fig. 4 for a lag and a constant wattage ballast. From measurements taken from these pictures, the crest factor (ratio of peak to r.m.s. current) on the lag ballast is 1.4 during starting and 1.5 during burning. The constant wattage ballast, on the other hand, has a crest factor of 2.7 during warmup and 2.1 during burning. This high crest factor is not necessarily inherent in the design of constant wattage ballasts, but was present in the design tested. As will be shown later, high crest factors will cause poor lumen maintenance.

Some Types of Ballasts Allow Highly Peaked Currents During Lamp Stabilization

Since mercury lamps are of the self-heated cathode type, a number of cycles are reqdired for the electrodes to reach operating temperature each

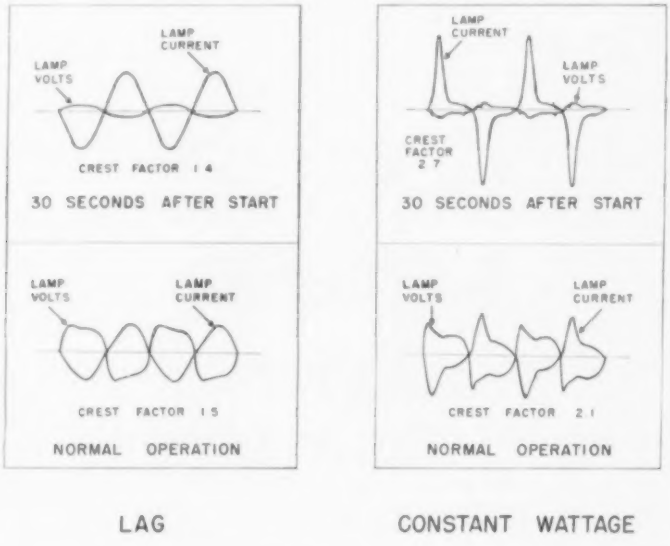

Figure 4. Lamp current and lamp voltage wave forms on lag and high crest factor constant wattage ballasts at 30 seconds after start and during normal burning for the 400-watt quartz mercury lamp.

time the lamp is started. For the lag ballast, using lamps of present design, the time to stabilize varies from 40 to 120 cycles.

During this starting period the lamp usually rectifies, the basic cause being the momentary ability of one electrode to supply electrons more easily than the other before uniform electrode temperatures are reached. The lamps will rectify first in one direction and then in the other, and these periods of rectification last roughly 20 cycles. During these periods there is, of course, a direct current component of lamp current, and the presence of direct current in the ballast magnetic circuit causes the iron to saturate and allow the current to go still higher. The most severe rectification causes current peaks to be about 50 per cent higher than normal, but the exact pattern is never repeated from start to start. A typical oscillogram of lamp current and lamp voltage during part of the starting period for a lamp on a lag ballast is given in Fig. 5.

The starting wave shapes of lamp current and lamp voltage for the constant wattage ballast are also shown in Fig. 5. Because there is a capacitor in series with the lamp, there can be no direct current component in the lamp current. These waveshapes are much more peaked than for the lag ballast, and our measurements show that lamps require up to several seconds and sometimes two or three minutes to stabilize completely. The crest factor is very high, about 2.7. The sharply peaked current wave shape and the longer stabilization time during starting cause excessive electrode evaporation and accompanying arc tube blackening at the starting period. As has been explained, the current crest factor is not quite so high after full lamp voltage is reached. It remains high enough, however, to cause excessive darkening of the arc tubes during life.

High Current Crest Factor Causes Poor Lumen Maintenance

We have tested 16 H400-E1 lamps of our manufacture and 10 lamps of competitive manufacture for lumen maintenance under controlled conditions on 10 ballasts having a crest factor of 1.5, and 10 ballasts having a crest factor of 2.1. The results of these tests, which are for vertical operation, are shown in Fig. 6. The lamps on this test were burned for 500 hours on lag ballasts and then photometered to make sure that they were normal before starting the special test. The lumen maintenance on the ballasts having the low crest factor is much superior to that of the ballasts with a high crest factor. For instance, after 4000 hours of additional burning, the lamps on the ballasts with a crest factor of 1.5 had 80 per cent of the 500-hour lumens, while those burned on the ballast with a 2.1 crest factor had only 43 per cent of the 500-hour lumens.

Summary

The watts supplied to a lamp burning on a lag ballast vary appreciably with variations in supply voltage, but scarcely at all throughout the range of normal lamp voltage tolerances. Series circuits and constant wattage ballasts supply a fixed lamp current, so individual lamp wattage and output vary greatly with individual lamps. Lead circuits are intermediate between the two classes.

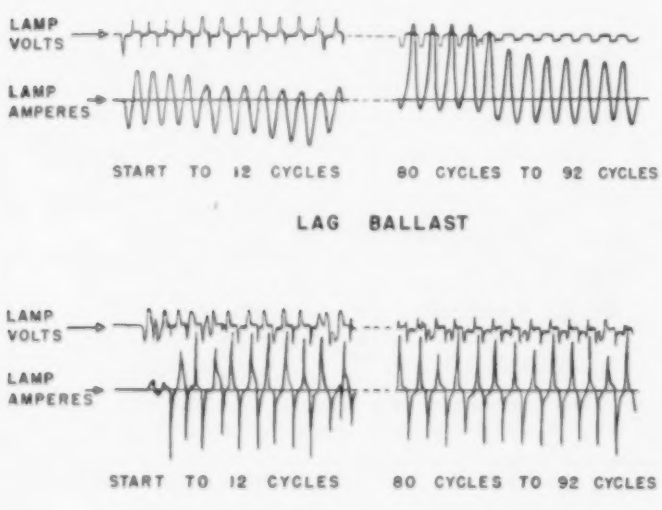

Figure 5. Oscillograms of lamp current and lamp voltage during the lamp stabilization period on lag and high crest factor constant wattage ballasts for the 400-watt quartz mercury lamp.

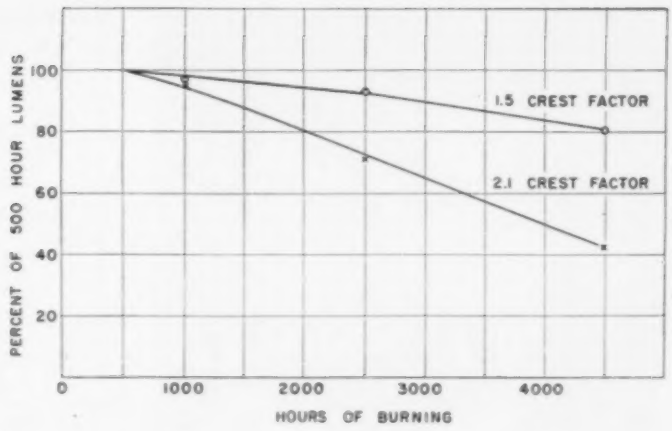

Figure 6. Per cent of 500-hour lumen output versus hours of burning for lamp current crest factors of 1.5 and 2.1 for the 400-watt quartz mercury lamp.

Lamp wattage and output are lower if the lamps are operated horizontally. Ballasts for horizontal operation can be designed to supply the additional watts to bring either the power consumed or the output back to rating. To reach rated lumen output the lamps must be operated slightly over design wattage. This is not harmful to lumen maintenance if line regulation and current wave form are good. However, where poor line regulation causes excessive lamp current, or where ballast design results in peaked current wave form, poor lumen maintenance will occur.

Acknowledgment

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DISCUSSION

H. U. HJERMSTAD:* It becomes apparent from this paper that there are differences in lamps and ballasts. The authors certainly have spent a lot of time in testing equipment under conditions which rarely exist in the field. Many engineers do not feel that what they have said is true of all types of ballasts and lamps. To my knowledge there are very few, if any, installations of multiple street lighting systems employing E-H1 or A-H1 lamps that use an indoor low-power factor ballast. This is the type of ballast that was apparently used for a comparison or a standard. One of the major causes of high crest factor in a ballast is the ratio of the open circuit voltage necessary to strike the lamp and the lamp operating voltage. I believe that the tests should have been conducted on a high-power factor, high reactance outdoor ballast for the most valuable information.

A constant wattage ballast having a crest factor of 2.1 is not realistic either. The company, which developed the constant wattage ballast system originally marketed an outdoor ballast with a crest factor of 1.75 to 1.9 at nominal voltage depending upon whose and what kind of lamp. Design improvements have resulted in crest factors of 1.62 to 1.75 and are currently being sold. We have many thousand constant wattage ballasts in service. To my knowledge we have never had a customer complaint due to rapid lumen depreciation.

Figure A is a typical photograph of our lamp life experience. These two E-H1 lamps have operated over 11,000 hours. The one with the greatest end blackening ran 11,240 hours on a high-power factor, high reactance

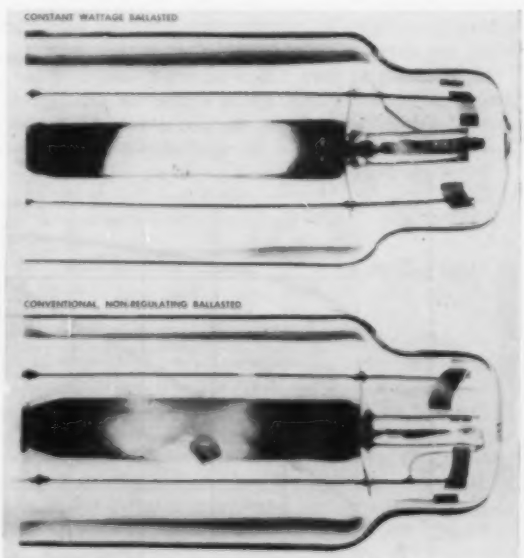

Figure A. Comparison of end blackening on field-operated E-H1 mercury vapor lamps. Top lamp operated 11,740 hours from constant wattage ballast. Lower lamp operated 11,240 hours from conventional non-regulating ballast. Both lamps are of the same manufacturer.

*Sola Electric Co., Chicago, Ill.

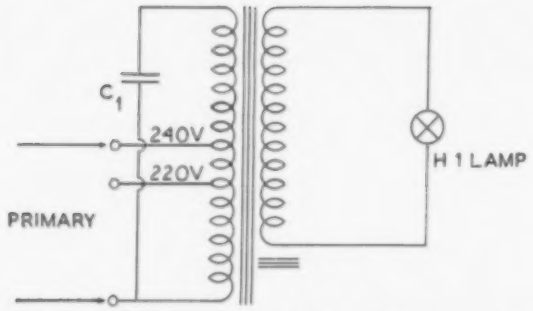

Figure B. Conventional, non-regulating high-power factor ballast circuit for H1 lamps.

		PRIMARY VOLTS					
		REGULATED TYPE 230 Volt Connection			NON-REGULATED TYPE 240 Volt Tap Used		
		200	230	260	200	230	260
FULL LOAD CONDITIONS	PRIMARY WATTS	466	473	480	350	442	543
	PRIMARY CURRENT	2.37	2.08	1.88	1.84	2.09	2.33
	LAMP VOLTS	135	135	135	134	135	136
	LAMP WATTS	410	418	424	310	390	474
	LAMP CURRENT	3.26	3.39	3.50	2.45	3.06	3.48
	WATTS LOSS	56.0	55.0	56.0	40	52	69
	EFFICIENCY %	88.0	88.5	88.4	88.6	88.4	87.2
	POWER FACTOR %	98.5	98.7	98.2	95.2	92.0	89.7
OPEN CIRCUIT	PRIMARY WATTS	37	37	40	45	60	80
	PRIMARY CURRENT	1.83	1.04	1.18	2.70	3.08	3.50
	LAMP VOLTS	302	336	318	370	295	335

Figure C. Comparison of electrical characteristics of constant wattage ballast and conventional non-regulating ballast for E-H1 lamps.

outdoor ballast having a crest factor of 1.61. The second or top lamp ran 11,740 hours on a constant w ttage ballast which had a crest factor of 1.89.

Figure B shows a schematic diagram of a high-power factor, high reactance transformer which is typical of the type usually employed for multiple street lighting. The capacitor C_1 provides for power factor correction over the primary extension winding. The secondary lamp current is limited through the high reactance secondary winding.

The characteristics of this type of ballast operating high pressure mercury vapor lamps are:

(1) Short warm-up time,

(2) High starting current which is frequently accompanied by lamp rectification with the starting current being as high as 30 to 60 amperes for periods as long as 60 cycles,

(3) Large variation in light output with line voltage changes.

(4) Large variation of lamp watts and current with line voltage changes. See Figs. C, D and E. For example at 200-volt primary lamp watts 310, 320 volts 390 watts and at 260 volts, 474 watts,

(5) Affected by lamp failure or power outage. When a lamp fails or power interruption occurs, the primary current of a high-power factor, high reactance ballast will increase to nearly double its nominal value. This may cause excessive ballast heating. With short time power failure all lamps on circuits go out. Upon restoration of power the lamps have such a high ignition voltage requirement that they cannot restrike. The primary current, however, is so high the main circuit breakers are caused to open,

(6) Open secondary circuit voltage of the ballast varies directly with primary voltage,

(7) The ballast primary voltage tap must be adjusted for normal line voltage at the time of installation. One has to hope that the line voltage will remain the same at all hours and seasons,

(8) Sensitive to line harmonic frequency content,

(9) Less change in lamp wattage but certainly not "scarcely at all" on high or low voltage lamps,

(10) Crest factor of 1.5 to 1.65.

The diagram of Fig. F shows a schematic arrangement of a suitable constant wattage ballast. It is basically a high reactance transformer in which the lamp and the power factor correcting capacitor C_2 have been placed in series. C_1 is a capacitor of such size as to resonate the secondary of the transformer to 180 cycles and thereby

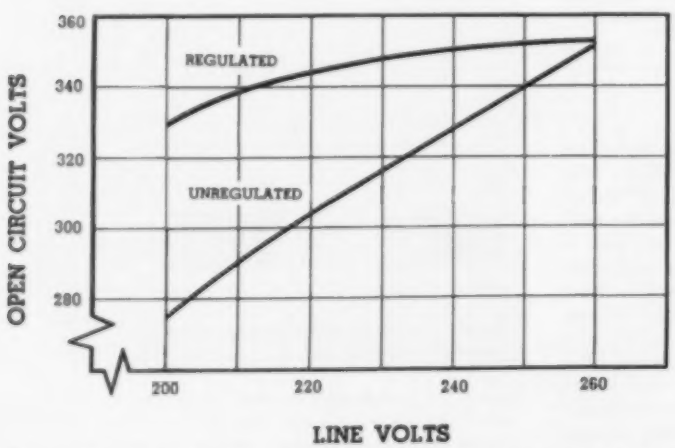

Figure D1. Open circuit characteristics, regulated type vs. unregulated type.

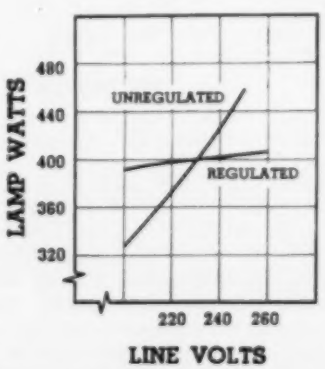

Figure D2. Lamp wattage regulation of D-H1 mercury vapor lamp, regulated type and unregulated type.

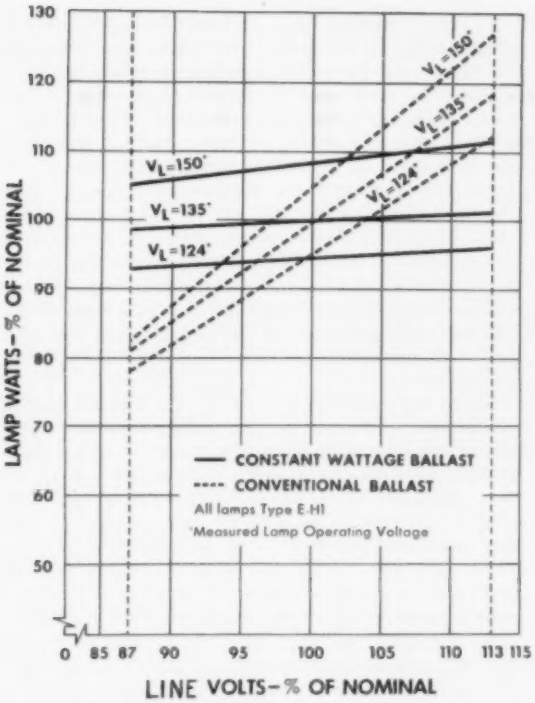

Figure D3. Lamp wattage regulation.

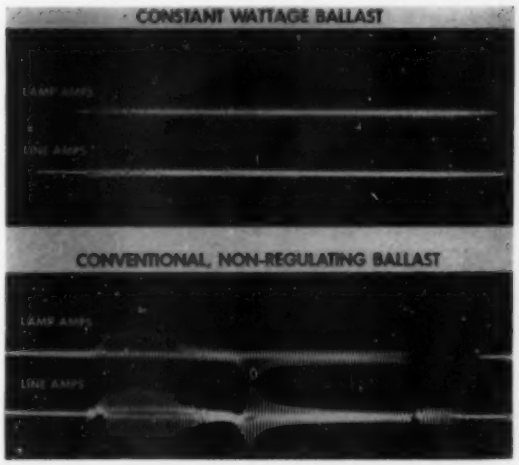

Figure E. Comparison of starting characteristics for constant wattage and conventional non-regulated mercury vapor lamp ballasts.

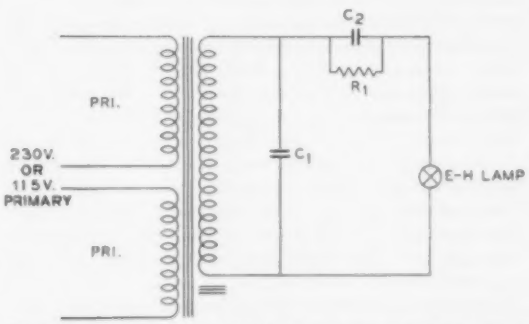

Figure F. Constant wattage ballast circuit for E-H1 type lamps.

maintain a high open circuit voltage with various primary line voltages. Once the lamp has ignited, C_2 is in series with the lamp and after the lamp has come up to full operating condition it operates at resonance to provide near unity primary power factor. The characteristic features of a properly designed constant wattage ballast are:

(1) Slow warm-up time, approximately 1¼ to 1½ times the requirements of a high-power factor, high reactance ballast,

(2) Open circuit voltage is regulated to provide better starting characteristics, especially for cold weather operation. See Fig. D1,

(3) Regulated lamp wattage. See Fig. D2,

(4) Regulated lamp light output,

(5) Open circuit primary current goes down with secondary shorts or opens due to lamp failures providing positive system protection. See Fig. C,

(6) No need for primary taps,

(7) Low starting current or surge currents rectification cannot take place. See Fig. E,

(8) Lamp does not extinguish due to line voltage fluctuations or dips,

(9) Excellent lamp life. Many lamps operating 10,000 to 15,000 hours. See Fig. A,

(10) Crest factor of 1.6 to 1.75,

(11) Recent ballast designs have brought the wattage of low voltage lamps up and high voltage lamps down. See Fig. D3,

(12) Not sensitive to line harmonics.

Summing it all up, the engineering features of the constant wattage or regulating type ballast are so far more desirable and practical that it is fast becoming the generally accepted standard ballast for mercury vapor lighting systems. No doubt this will be true when everyone gets through re-inventing it.

I have a few questions for the authors. They are:

(1) What is the maximum crest factor permissible for (a) a 400-watt E-H1 lamp, and (b) a 400-watt A-H1 lamp?

(2) What is the maximum permissible current that an E-H or A-H lamp can tolerate and eliminate end blackening

(3) What is the maximum permissible operating wattage to prevent end blackening?

(4) A-H1 and E-H1 lamps have been out for several years. As yet, no American Standard for ballast impedance has been developed. What is the recommended ballast impedance to provide 400-watts (a) for outdoor use, and (b) for indoor use? What are the open circuit voltages for these impedances?

(5) When ballasting fluorescent lamps, low lamp current will cause excessive end blackening. Is this also true of high pressure mercury vapor lamps?

(6) What is the lamp current that will bring the cathode of an A-H1 lamp up to operating temperature?

(7) What is the lamp current that will bring the cathode of an E-H1 lamp up to operating temperature?

(8) Did the authors run any tests of A-H1 lamps under

the same conditions of the paper? What were the results of these tests?

(9) On page 520 the authors show that 26 lamps were tested on 20 ballasts. No doubt this was a typographical error. Were all these lamps of center voltage?

(10) What were the complete electrical specifications of the two types of ballasts tested both under operating conditions and open circuit secondary conditions?

A. E. Feinberg:* I wish to congratulate the authors of this paper on the summation of a problem which has been facing ballast designers for some time.

I have been aware that the problem of crest factor relative to lamp current existed, but did not have a full understanding of its ramifications until this paper was presented.

The lag type ballast with power factor correction can be manufactured with crest factors on the order of 1.5, but it leaves much to be desired relative to regulation. However, if there is a considerable loss in lumens maintenance with high crest factor such as indicated in many of the so-called constant wattage type ballasts, the ballast designer wonders whether a compromise between regulation and crest factor might not be desirable. An examination of several different makes of constant wattage type ballasts indicates that high crest factors are common with these ballasts. This is no doubt indicated by the economics of ballast design, and it may be quite possible to make a constant wattage ballast with a considerably lower crest factor. The cost of such a ballast may not be economically feasible. The variation of the wattage between different lamps with the constant wattage ballast indicates that there are defects in the use of the constant wattage ballast which could cause as much damage to lamp life as with a moderately varying voltage and a lag type ballast with voltage taps.

Our research indicates that it is possible to vary crest factor inversely with the degree of regulation and at the same time provide a ballast of economical design. This means that at a crest factor of relatively low level — 1.6 to 1.7 — it is possible to design a ballast of approximately linear regulation, that is, a 10 per cent voltage variation would cause 10 per cent wattage variation. This type of ballast would have characteristics similar to that shown for the lead type ballast and would be considerably less expensive to manufacture. The regulation could be improved at the expense of crest factor.

It is up to the ultimate user and the lamp designer to evaluate the factors of regulation, lumen maintenance, and cost; and then inform the ballast designer of the desired limits which would be the most satisfactory compromise within the limits of economical ballast design.

J. M. Harris:** The effect of ballasts and associated circuitry upon mercury lamp operation is very important. Ballasts have a profound effect on the mercury lamp, and the design may materially affect lumen maintenance and life. May I congratulate the authors for their presentation of the analysis of these operating variables on mercury lamp performance.

I agree with the authors in many instances. However, there are several items which I feel should be enlarged upon with more complete data and figures in order to make the paper more effective.

*Vice-President, Product Design, Advance Transformer Co., Chicago, Ill.

**Sylvania Electric Products Inc., Salem, Mass.

(1) Little mention has been made of the number of lamps involved in the various conclusions. Over extended life tests there can be considerable variation in lumen maintenance from lamp to lamp — even when tested under laboratory conditions. Any kind of life test on a small number of lamps may show a trend, but to pronounce sentence on any ballast or lamp without considerable field and factory substantiation would be misleading.

(2) Another item not mentioned in the data is the type or types of constant wattage ballasts or the type of lag ballast used. The indoor ballast has a low open circuit voltage compared with a high open circuit voltage of the constant wattage ballast. If the indoor ballast was compared with the constant wattage ballast, the results would not be comparable.

During the past year we have recorded many current waveforms and calculated the resultant crest factors of several types of constant wattage ballasts. Rarely have we found results so poor. As a matter of fact some of the later constant wattage ballasts tested show maximum crest factors (within the primary voltage range) of 1.85. This seems quite acceptable even through the crest factor during warm-up is as high as 2.25. These results indicate that the authors' conclusions concerning the crest factor itself seem to be somewhat incomplete.

(3) I believe the authors' reference to rectification was under-emphasized. Excluding series and constant wattage ballasts which virtually eliminate rectification effects, rectification currents usually exceed the lamp current by more than 50 per cent. Oscillograph records show some ballasts with peak rectification currents three to four times the normal current on indoor ballasts and still higher on other outdoor types. Although most lamps can stand these high surges, adequate design to limit this excessive current should benefit the lamp user.

(4) An arc tube voltage of ± 15 volts does represent the industry limits. This is a limit and no manufacturer takes full advantage of this spread. Seldom does an arc tube voltage vary more than ± 10 volts and in many cases a majority of the arc tube voltages range within ± 5 volts of center. Therefore, the constant wattage term is adequate for a large majority of all commercial lamps.

As a final note, in the introductory remarks mention was made that either soft or hard glass outer jackets are used in standard quartz lamps. It was reported at the Thirteenth Annual M.I.T. Conference on Physical Electronics in 1953 by C. Kenty of the General Electric Co. that the expected life and lumen maintenance would be decreased if hard glass outer jackets were used. The reason given was that H_2 from hard glass outer jackets diffuses through the quartz arc tube and contaminates the thorium on the cathode. I would be pleased to know if these findings are obsolete.

Herbert O. Rost:* This excellent study on the effects of changes in line voltage and the observance of certain tolerances in lamp manufacture on the performance of mercury lamps is based on the commercial arc voltage range of 120 volts to 150 volts with 135 volts as center voltage. It is, however, not the lamp voltage that affects the lamp performance but rather the impedance of the lamp which in itself is determined by manufacture, age and lamp history, as well as by outside circumstances, mainly the temperature. This lamp impedance is never-

*Jefferson Electric Co., Bellwood, Ill.

theless of a well determinable and readily to be agreed upon value for any lamp operated over a standard reactor after a certain aging period. An H 400-E 1 lamp with an inherent effective impedance of 33.3 ohms when operated over such a reactor will draw a current of 3.6 amps which in turn develops a voltage of 120 volts across the arc. The corresponding values at 42.3 ohms (center-voltage lamp) would be 3.2 amps and 135 volts, and with a lamp of 53.3 ohms, 2.8 amps and 150 volts are to be expected. We know that this impedance actually represents a resistance which by virtue of the fact that the shape of the arc voltage considerably deviates from a sinusoidal wave appears to be an inductive impedance. It is this apparent impedance value that affects the lamp performance, and it is nothing else but this impedance that could possibly be seen by the ballast.

While the range of the lamp voltage tolerances amounts to not more than ±11 per cent, the effective lamp impedance Z (arc voltage in rms divided by lamp current in rms, the latter practically being sinusoidal) varies over a range from 79 to 126 with 42.3 ohms as 100, i.e in the ratio of 100 to 160.

Based on the figures as given by the authors there is no ballast in any of the cited four groups of lamp ballasts that would exceed this ratio as far as the wattage delivered to the lamp is concerned. Even under ±10 per cent change in line voltage the lamp wattage would stay within 77 and 124 with 100 for a center-voltage lamp operated over any of the four ballasts from nominal line voltage. The table shows how the lamp impedance and the change in line voltage affects the wattage to the lamp (lamp in vertical position).

An H 400W — E 1 Lamp with:			
Z_{La} (ohms)	33.3	42.3	53.3
I_{La} (amps)	3.6	3.2	2.8
V_{La} (volts)	120	135	150
will operate at ..... % wattage at			
% of nominal line voltage	90/100/110	90/100/110	90/100/110
on Lag Ballast	80/102/124	78/100/122	77/98/120
on Lead Ballast	81/91/101	89/100/111	97/109/121
on Series Ballast	90/90/90	100/100/100	107/107/107
on Constant Wattage Ballast	90/90/90	100/100/100	110/110/110

This chart is self-explanatory. Since there are lag ballasts on the market responding to line fluctuations of ±10 per cent (in volts) with not more than ±15 per cent change in wattage, corresponding to only ±20 per cent change in light output, the total range of lamp wattage tolerances has been considerably narrowed down. Further efforts will have to be directed against even narrower limits, by the ballast manufacturers as well as by the lamp manufacturers. No doubt that certain improvements in the lead and constant wattage circuit, as outlined by the authors, are indicated.

Answers on two questions of minor importance would be appreciated: (1) Is the scale applied to lamp amperes in Fig. 5 the same for the constant wattage transformer as it is for the lag ballast? (2) What are the open circuit voltages of the ballasts in Fig. 6, and on what line voltages have the ballasts been operated?

C. H. BURNS:* This paper gives data not generally known to users of mercury lamps and not previously compiled under one heading. The authors should be commended for their work in compiling these data.

There are several questions I would like to ask the authors:

(1) Since the ratio of open circuit voltage supplied by the ballast to operating voltage of the lamp affects those data shown in this paper, it would be desirable to know the open circuit voltage of the several types of ballasts used in securing these data.

(2) On page 519 of the paper, under the heading "Some Types of Ballasts Have Poor Current Wave Form," the author makes the following statement:

> "If the current wave form is badly peaked, both the increased rms value of current and the high peak value greatly increase the blackening created during the sensitive low-pressure period."

I would like to ask if this means that a higher crest factor on lamp current is permissible during operating than during starting. I would also like to hear the authors' recommendations on lamp current crest factor limits under both starting and operating conditions to secure rated life and lumen maintenance.

P. B. CLARK:** When I read the title of this paper I thought here would be a treatise on all variables affecting the operation of mercury vapor lamps. Disappointment followed, however, when I found that the one great variable (input voltage variation) was passed by with very little analysis or comment and comparative conclusions were arrived at giving it little consideration.

How does an engineer or lineman select the proper tap when installing a ballast having multiple tap input windings? In street lighting this is almost an unsolvable problem. If the ballasts are being installed on a circuit that is used for street lighting only, then the IR drop between ballasts can be computed and a selection made on that basis. Feeder voltage variation, however, is the stupendous problem to surmount. Distribution engineers wrestling with the problems of line voltage are faced with the following dilemma:

(1) Day time industrial load.

(2) Day time and evening air conditioning loads that may be exceptionally heavy during certain seasons.

(3) Water heater, cooking, lighting load, etc. superimposed on this in the early evening hours.

(4) Great reduction of practically all of this load during the late night and early morning hours.

Does the street lighting engineer base his tap selection on a voltage that exists during the day or early evening hours when the loads are extreme and the voltage low or does he base it on a condition that exists during the wee hours of the morning when the line load is extremely low and the voltage is excessively high? If the distribution engineers have used unswitched distribution capacitors for power factor correction, in order to improve their heavy load line conditions, the street lighting engineer has a real problem when the reactive line load is low.

These, I feel, are the variables that really cause mercury vapor lamp operating problems, especially on street lighting applications.

The constant wattage ballast due to its regulating characteristics, and it alone, has the desirable characteristics to solve these problems without expensive system analysis and modification.

The authors have not pointed out one extremely desirable characteristic of constant wattage ballasts. The constant wattage ballast losses under no-load conditions are of a lower magnitude than when operating a lamp. Many other ballasts have extremely high losses when energized without load. This results in extreme operating temperatures, espe-

*Electrical Components & Circuits, Westinghouse Electric Corporation, Cleveland, Ohio.

**Line Material Co., South Milwaukee, Wis.

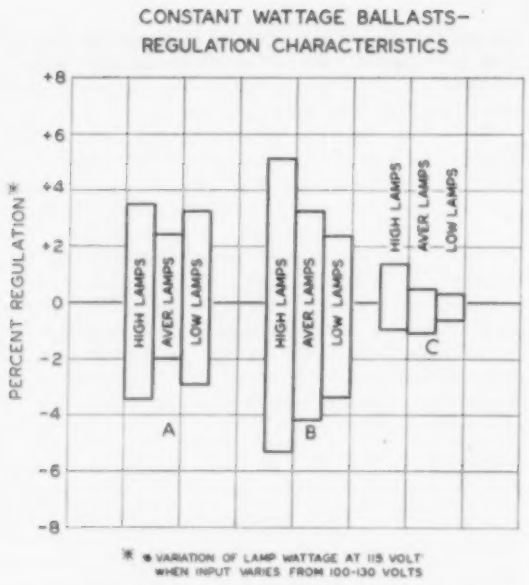

Figure G. Constant wattage ballasts — regulations characteristics.

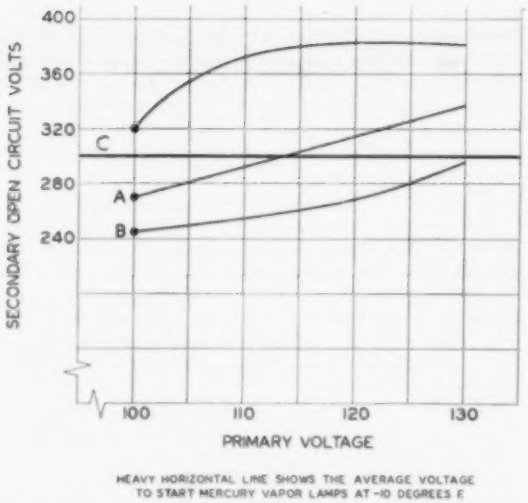

Figure H. Constant wattage ballasts — open circuit characteristics.

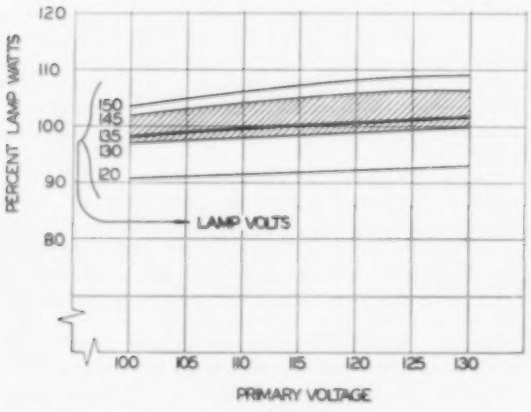

Figure I. Regulation Characteristics of Group C constant wattage ballasts for 400-watt Type H 1 mercury lamps.

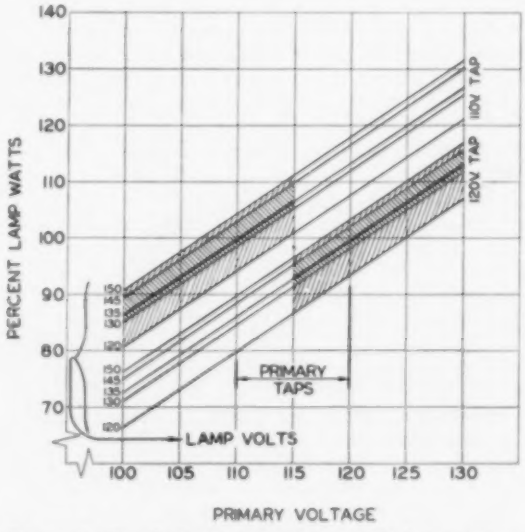

Figure J. Regulation characteristics of high reactance type ballasts for 400-watt Type H 1 mercury lamp.

cially in certain portions of the winding and the resultant deterioration of insulation and ballast failure.

I feel that it is likely and extremely unfortunate that this paper might cause readers to conclude that constant wattage ballasts represent just another and perhaps mediocre method of operating mercury vapor lamps. This certainly could not have been the authors' intent and it is unfortunate that they used constant wattage ballasts having such poor characteristics for their test work and studies.

It should be borne in mind that there are several so-called constant wattage ballast designs. Fig. G of this discussion shows the regulation of three constant wattage ballasts having different type circuits. The graphs were plotted from test data taken in our laboratories. Lamps with voltages as low as 120 volts were used as well as lamps with voltages as high as 150 volts. Input voltage to the ballasts was varied from 100 volts to 130 volts. The graph bars on the right show the excellent regulation that can be obtained with proper constant wattage ballast circuits even when operating with all the variables that can be encountered. It should be noted that each bar of the graph represents regulation above and below the particular mean wattage for that group of lamps.

Fig. H shows the open circuit voltage provided by these ballast circuits. The ballast represented by the top line of this graph reliably starts and warms up lamps to operating temperature conditions at temperatures of —20 F and below. Lamps of several makes both new and old were used in these tests. Ballasts of this type have operated for several winters in Alaska where the temperatures have been

extremely low for prolonged periods of time and completely reliable starting and operation have been experienced.

Fig. I is a graphic portrayal of the regulation characteristics of the constant wattage ballast that we supply. It should be noted that several lamp manufacturers indicate that better than 90 per cent of the lamps which they sell fall within a voltage range represented by the shaded area of this graph.

Fig. J is a graphic portrayal of the regulation characteristics of high reactance, high power factor type ballasts for 400-watt Type H-1 mercury lamps. This graph is plotted from test data taken in our laboratories when testing a ballast of this type that is in common use for street lighting at present. It should be noted that this ballast has two primary winding taps. I believe it clearly portrays the problems that I discussed in the beginning of this comment.

I would like here to make mention of a paper published in Canada and authored by Mr. P. Shane. The title is "A Brief Report on Experience of Manitoba Power Commission with Conventional and Constant Wattage Mercury Vapor Ballasts." The paper covers the problem of ballast failures and should prove extremely enlightening to anyone using mercury vapor lamps. It deals with the problem of harmonics on circuits supplying mercury vapor ballasts.

There are other technical points and questions that I felt warranted discussion but others have commented on them and I shall refrain.

F. D. WYATT:* This paper is of value in that any new information on mercury lamps and their auxiliary ballasts are of great interest, due to the growing use of this type of lamp for street lighting.

I wish to question the apparent criticism of constant wattage ballasts. We have used a considerable number of these with excellent results, and we have no reason to suspect that the constant wattage ballast per se causes either a reduction in life or lumen output.

The great advantage of these constant wattage ballasts is the wide voltage regulation permissible, with essentially constant lumen output, which permits considerable economies in copper wire sizes.

This causes us to look somewhat further at the results of these tests.

The first question which should be investigated further is the crest values of the particular ballasts tested. It is my understanding that the constant wattage ballasts with which these tests were made are indoor units with 200 volts maximum for starting, low power factor and with a crest value of 2.1. This ballast is not comparable with present day ballasts of the type which are in general use. All of the constant wattage ballasts which we have used are of the high-power factor type, with 300 to 325 volts open circuit and with a crest value not to exceed 1.75. The difference in the crest values, open circuit voltages and power factor of the ballast will undoubtedly make a difference in the life of the lamp and its resulting lumen output.

The second question pertaining to the method of tests is that the impressed line voltage was held constant. It appears that the tests were made with constant voltage supply, which is a condition not actually achieved in service. The constant wattage ballast is made primarily for a fluctuating voltage supply and the conventional type multiple ballast suffers greatly with a fluctuating voltage supply. It would be most desirable to make this comparison on a basis of actual service conditions .

It is suggested that these tests be continued with a fluctuating voltage as found in service, and with high-power factor ballasts to make further comparisons.

W. S. TILL:* In commenting on this interesting paper I would like to ask the question: "What effect on lumen maintenance results from the operation of an E-H1 mercury lamp on a ballast having a lamp current crest factor of 1.7; and similarly, one of 1.85?"

Although the authors' objective in studying the effect of peaked current wave shape is commendable, their tests apparently were limited to ballasts having crest factors of 1.5 and 2.1. As a result, the data plotted in Fig. 6 may lead to the inference that lumen maintenance becomes poorer with any crest factor value above 1.5, but we feel that such an interpretation would be questionable. Do the authors have any other evidence or an opinion regarding the nature of the function; that is, is lumen maintenance satisfactory up to some critical value of crest factor, or is an exponential function involved?

Our tests of ballasts having a lamp current crest factor of approximately 1.85 have shown no adverse effect. These tests have been conducted ever since the constant wattage type of ballast was first introduced, and they are continuing. Lamps tested have been limited to those of our own manufacture.

Regarding the choice of 412 watts for horizontal operation of E-H1 lamps, I would like to point out that we selected this value in order to obtain the same light output as in vertical operation, *without* sacrifices of safety factor in the lumen rating. I received a somewhat different impression from the paper, but this could be due to design differences in lamps tested, as we found considerable variation among different brands. All lamps tested with photometered after stabilization at various angles of rotation about the horizontal axis so as to eliminate errors in positioning to the greatest possible extent.

I note that the maintenance curves of Fig. 6 are shown in terms of 500-hour performance for the understandable reasons given in the paper. Since it is customary to publish maintenance data based on performance at 100 hours, comparison with other curves should be made with this difference in mind.

C. W. KRONMILLER:** This paper illustrates the wide variation of operating characteristics that can be obtained using different types of ballasting circuits on the same lamp. Consideration was given to the effect of lamp and line voltage variation on lamp performance. In actual lamp operation in the field, consideration must also be given to the manufacturing tolerances necessary for the production of ballasts.

I believe these points indicate a definite need for industry standards for both mercury lamps and mercury ballasts. The authors are to be congratulated for taking a necessary step in this direction.

I would like to ask the authors if they have more specific information on what they consider excessive lamp current.

J. PETERSON:† I think this paper is a very comprehensive treatment of the behavior of the 400-watt E1 lamp under various operating conditions. As a representative of a

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**Sylvania Electric Products Inc., Salem, Mass.
†General Electric Co., Lynn, Mass.

manufacturer of street lighting equipment, we feel that the data presented by the authors is a clarification of a subject that was rapidly becoming somewhat confused, to say the least. In particular, we welcome the data on horizontal burning because the majority of street lighting luminaires using the 400-watt lamp now operate the lamp horizontally.

I think it is obvious from the data that there is no ideal ballasting system which can be universally applied to all types of installations. We have supplied ballasting equipment for all the various types mentioned in the paper and, in general, these systems have performed satisfactorily in the eyes of the user, especially when he has understood the limitations that have been set forth in this paper. Individual lead ballasts are not being used today to the same extent that they were in the early days of mercury street lighting. Conventional lag ballasts represent the most popular type in spite of their sensitivity to primary voltage variation. Downtown areas supplied by networks or systems with good voltage regulation seem to be well suited to the lag ballasts. Proper use of the taps on the lag ballast seems to be a practical way to overcome the effects of line drop in systems where a number of lag ballasts are controlled from a common contactor. Where primary regulation is poor or the tap selection problem is involved, then the constant wattage ballast might be the answer. Incidentally, the paper indicates that the term "constant wattage" is somewhat misleading in that this type of ballast does not deliver constant wattage to all lamps. We prefer to call this type of ballast a regulator ballast because the ballast essentially regulates the output current to a constant value and hence only holds constant wattage to the particular lamp that it is operating and that value of constant wattage will vary from lamp to lamp as the arc drops in the lamps vary from 120 to 150 volts.

The crest factor limitation mentioned in the paper can be improved by some new ballast circuitry; details on this circuitry will probably be available at some future date. Such a device with an improved crest factor is available at the present time.

With regard to series circuits using ILH ballasts, it could be stated that the extremes of wattage due to all causes are never as great as on other types of ballasting and it is our impression that lamp performance on series circuits is better than on multiple circuits with lag ballasts where wide swings of primary voltage are encountered.

The lead and lag data given in the paper were apparently taken on a 230-volt open-circuit voltage ballast. Most street lighting ballasts use 300 volts open circuit voltage and these ballasts show less change in other characteristics for a given change in line voltage. For instance, on a 300-volt ballast the output wattage varies approximately as the 1.5 power of the primary voltage as compared to roughly the square of the voltage in the case of the 230-volt open-circuit ballast.

In summary, let me emphasize again that this paper should prove to be a valuable tool in the hands of a user in evaluating lamp performance on various types of ballasting systems.

E. B. Noel and E. C. Martt:* First of all we wish to thank all of the discussors of our paper for their comments. They have brought out many important points and we hope that, along with our replies, these discussions will increase the usefulness of our paper.

Since several of the same questions were asked by many of the discussors of our paper, we will try to answer these first collectively. Some of these questions arise from a misinterpretation of the purposes of our paper, which are as follows: First, to summarize lamp behavior resulting from different primary voltages and different lamp voltages on typical ballasts. Second, to show the effects of horizontal lamp operation with the different types of ballasts, and third, to show how lamp current wave shape affects lumen output which the user cannot easily measure. We stated definitely that we are not condemning the constant wattage ballast. We are primarily interested in obtaining good lamp performance regardless of the type of ballast used, and we believe that these conditions can be obtained in all types of ballasts. It is true that in the tests involving high current crest factor we used a constant wattage ballast. This is not to say that all constant wattage ballasts have a highly peaked lamp current wave shape. We are certain that some of the early designs of the constant wattage ballasts did have a high crest factor, and we used one of these designs to determine the effect of crest factor on lumen maintenance. We recognize that this ballast type has many assets, and we do not intend to detract from these. We gather from the discussion of our paper that the manufacturers of these ballasts have taken definite steps to improve the lamp current crest factor. This is encouraging news.

Many discussors questioned the 2.1 value given to the lamp current crest factor of the test ballasts used. This value was arrived at by three separate methods, and we believe it to be substantially correct. We believe there is need of an accepted method within the mercury lamp industry as there is within the fluorescent lamp industry for measuring crest factor. We hope that one of the results of these discussions is that an ASA Committee will recommend suitable methods for measuring the peak to rms ratio.

Many asked for specific details of the ballasts compared. The lead-lag ballast used was one manufactured by our own company for indoor operation and had open circuit voltage of approximately 228 volts with center primary voltage and a short circuit current of 4.8 amperes on the lag side and approximately 3.2 amperes on the lead side. The constant wattage ballast used had an open circuit voltage of 350 volts and a short circuit current of 4.8 amperes. Since the ballast was not of our own manufacture, we will not describe it further. Despite the differences in open circuit voltage between these two ballasts, we believe the tests to be comparable. For instance, as a result of many tests we have shown statistically that there is no difference in life or lumen maintenance between the lead and lag ballasts. We have further shown that a high reactance outdoor ballast with an open circuit voltage of more than 350 volts gives performance comparable to that of the lead-lag ballast when the lamp crest factor and other operating conditions are the same. We conclude from this, that within the range studied, the value of open circuit voltage is not an important factor in lumen maintenance. The factors which most affect lumen maintenance from a ballast standpoint are the absolute value of lamp current, the lamp current wave shape and the starting transients if the lamp is started often.

Several discussors asked for complete ballast specifications that manufacturers could follow. These are being written at present by ASA Committee C82. Until these specifications are written, our own company recommends a maximum crest factor of 1.7 for both starting and operating, measured by means of a peak-to-peak meter with an rms meter, or by means of a good cathode ray oscillograph.

*Authors.

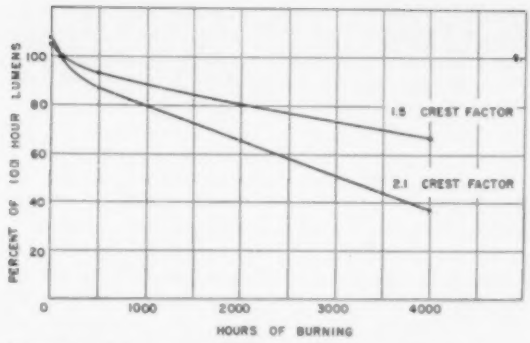

Figure 7. Per cent of 100-hour lumen output vs. hours of burning for lamp current crest factors of 1.5 and 2.1 for 400-watt quartz mercury lamps made by Competitor "A."

We also recommend that, with a lamp having center voltage operated by a ballast with rated or center voltage on the primary, the lamp current shall not exceed 110 per cent of nominal, nor shall lamp wattage be less than 90 per cent of nominal. The minimum current shall be that corresponding to the 90 per cent wattage value.

Since this paper was presented, we have obtained additional photometry of Competitor "A"'s lamps which have now been burned to 4000 hours. Five lamps were burned on 1.5 crest factor ballasts and five lamps were burned on 2.1 crest factor ballasts during the entire test. The results are shown in the accompanying Fig. 7. It is apparent from these curves that there is a decided difference between the lamps burned under these two conditions. For example, at 4000 hours the lumen output is 66.5 per cent of the 100 hour reading on the 1.5 crest factor ballast, and 37.2 per cent of the 100 hour reading on the 2.1 crest factor ballast. We realize that more testing would be necessary to determine actual numerical differences, but these curves definitely indicate that a considerable difference exists. On the basis of this test, we are certain that the problem is not limited to the lamps of only one manufacturer.

The following are our comments on Mr. H. U. Hjermstadt's discussion of our paper. First of all, Mr. Hjermstadt states that we have spent a lot of time in testing equipment under conditions that rarely exist in the field.

Does he mean by this that primary voltage never changes in the field? Or that lamps are never burned horizontally, and that all ballasts produce the same current crest factor? We are certain that all of these variables occur but that most users are not in a position to test and evaluate them. It is the purpose of our paper to contribute toward this end.

We have not limited our paper to discussion of street lighting problems only. It is true that the indoor lag-lead ballast is rarely used for street lighting because of different operating conditions, but it was used as a control ballast because it is the most common ballast used for general lighting. At the present time, there are about three to four times as many mercury lamps used for industrial lighting as for street lighting. It is for this reason that we chose the lag ballast as our control. It is true that the high power factor high reactance outdoor ballast is most commonly used for street lighting. As stated previously, a good design of this ballast will have a lamp current crest factor no higher than a good design of the lead-lag ballast. Changes in primary voltage will affect lamp operation differently, of course, on the high reactance ballast in comparison with the lead lag. However, the behavior of this ballast will fall somewhere between the lead and the lag circuits, and we believe that the effect of high current crest factor will be just as damaging in a poor design of the high reactance type as in the poor design of any other type of ballast.

Mr. Hjermstadt states that a constant wattage ballast having a crest factor of 2.1 is not realistic. When our tests were started, constant wattage ballasts obtainable on the open market were used and the crest factor measured on these ballasts was as reported in our paper — 2.1 for normal operation, and even higher during lamp starting. One cause of the disagreement of the value of lamp current crest factor might possibly be our measuring technique. We actually used three methods, all of which agreed closely. The first was that employing a meter reading peak current values combined with a meter reading the rms value. The second method used an oscilloscope which was calibrated so that the ratio of peak to rms could be obtained. The third method involved a magnetic oscillograph having a frequency response flat to 5000 cycles per second. The peak to rms ratio was obtained graphically from traces of lamp currents. This method would not usually be used because of the labor involved. Since all three of these methods agree that the value should be 2.1 within 10 per cent, there is no doubt that the ballast tested had this ratio. We would hope that if Mr. Hjermstadt measured the crest factor on these same ballasts, then the results would be the same. We are curious to know what method Mr. Hjermstadt uses in measuring lamp current crest factor. As we stated before, we believe that there should be an industry standard for measuring current crest factor for mercury lamps as there is for fluorescent lamps.

Mr. Hjermstadt shows pictures of two EH-1 lamps that have operated over 11,000 hours, one on a high power factor high reactance ballast and the other on a constant wattage ballast. Evidence based on only two lamps after this number of burning hours is worthless because of the tremendously wide variation in output in mercury lamps after long hours of burning. A repeat test of this type could very easily show a reversal. In our own tests where a total of 26 lamps were used and which were carefully photometered at many intervals during lamp life, we consider our curves to be only indicative of lamp performance and certainly not conclusive enough to establish numerical differences. The important data that Mr. Hjermstadt should furnish is a lumen maintenance curve from 0 to 6000 hours with several photometry intervals. Photometry should be done in a calibrated sphere. Mercury lamps will burn well beyond their economic life and the lamps that Mr. Hjermstadt has pictured should have been removed many thousand hours previously. Proper life testing of lamps is a very long and expensive process, and we realize that ballast manufacturers cannot always be equipped with the best photometry methods. We are certain, however, that visual inspection of lamps is not a substitute for accurate photometry and should not be used as the basis for designing ballasts.

Mr. Hjermstadt lists many items which he considers to be advantages of the constant wattage type of circuit. We certainly agree with him that this general type of circuit does have many operating advantages. The most important of these are the elimination of primary voltage taps and the comparative lamp stability due to dips in the primary line voltage as well as low inrush current and low primary current if a lamp is out. It also maintains a very uniform wattage and lumen output with respect to changes in pri-

mary voltage. As we have pointed out in our paper, however, it is not strictly constant wattage with respect to different lamp voltages. Lamp wattage and lumen output will vary somewhat from lamp to lamp. He states that this type of ballast also gives a slow lamp warmup time. Here again, careful measurements are necessary under specified conditions. However, we have found that most of the constant watttage ballasts on the market today are very satisfactory with regard to lamp warmup in a fixture at low ambient temperatures. We do not understand why Mr. Hjermstadt states that approximately 1½ to 2 times the length of time is required for warmup on these ballasts. We have found that warmup time is nearly that for the lag ballast.

He states that low starting current or surge currents due to rectification cannot take place. In his Fig. E, he shows oscillograms of lamp and line currents during the first 60 or so cycles of lamp starting. We agree that the curves shown for the conventional lag ballast are nearly the same as we have found and are as found in our Fig. 5. His curves for the constant wattage ballast show very smooth starting compared to the lag type ballast. Actually, his curves are misleading in this respect. The amplitude and time scales are too small to show details of the wave form of the lamp current during starting. We have found that if the lamp current wave shapes are examined in detail during the stabilization period on a constant wattage type ballast it will be found that the lamp currents are extremely peaked, and in many cases the lamp current does not seem to flow during half cycles. This spiked wave has an effect that can be heard as a ringing sound in the lamp during the first few seconds of starting. We believe that this wave shape as shown in our Fig. 5 can and does cause as much lamp end blackening as lamp rectification in other types of ballasts.

Mr. Hjermstadt has made the statement that excellent lamp life is obtained on a constant wattage ballast and that many lamps are operating from 10 to 15 thousand hours. This may well be true, but the long life is not nearly so much a function of the ballast design, as it is of lamp design, and he fails to state that the light being obtained from lamps of this long life is in many cases as little as 10 per cent of the original output; hence, merely to say that long lamp life is an advantage on a certain type of ballast is to leave out the important thing that a lamp user buys — the mean lumens obtained from the lamp during its life.

In regard to recent designs of the constant wattage ballast that have allegedly brought a low wattage lamp up in wattage and the high wattage lamps down, we believe that this is commendable if it is done without sacrifice to lamp operation in some other manner. We would be very interested to see data on lamp performance with respect to changes in lamp voltage on this design.

It may well be that the engineering features on this constant wattage or regulating type ballast will make it more desirable for many applications than the lag ballast. We only hope that the designer of this type of ballast will consider the lamp maker's problem and will remember that lamps are purchased to produce light and that the ballast that operates them must not only be convenient to use, but will be compatible with the aims of producing the best light output.

In regard to Mr. Hjermstadt's specific questions, we recommend a maximum current crest factor of 1.7 for both the E 1 and the A 1 lamps. We have tested the A 1 lamp under conditions similar to those shown in our paper with respect to operation on different ballasts, operating positions, and changes in primary voltage. Except for the use of a deflecting magnet on the A 1 lamp, the graphs will be about the same as those shown for the E 1 lamp. We have not, however, sufficiently life-tested the A 1 lamp on high crest factor ballasts.

The statement that 26 lamps were tested on 20 ballasts is not a typographical error. We naturally reuse the ballasts that we have. Most of the lamps tested were not chosen for center voltage.

The control ballasts used were the 89G15 manufactured by our own company. We are not free to give the name of the company which manufactured the ballasts having a 2.1 peak to rms ratio.

We agree with Mr. Feinberg that the so-called constant wattage ballast can be designed with a reasonable peak-to-rms ratio and our own company is now producing such a ballast. Other ballast manufacturers have also stated that they either have at present or are working on a ballast of this type having a low crest factor. We believe that these efforts are commendable and will result in more light to the lamp user.

In regard to Mr. Harris's comments, we have shown in our paper the number of lamps that were tested. We would, of course, have liked to have tested a larger number of lamps, but the testing of a large number of lamps is very expensive. Often more than a year is required to complete a single life test. The data that we present with respect to life testing on the high crest factor ballast intended only to indicate a trend and not to supply absolute figures for comparison. We believe, however, that the trend was so definite to allow us to make preliminary conclusions, and our repeat test, which at present is out to 4000 hours, is showing substantially the same results. See Fig. 7. We wish to call attention to this trend so that ballast manufacturers could try to correct it.

We agree with Mr. Harris that lamp currents can exceed by more than 50 per cent the normal operating current if the lamps rectify, and our paper is in error on this figure. A maximum value of peak currents that we have found have been 500 per cent of the peak value of normal operating current and this higher value was found on lamps which had one electrode intentionally deactivated to represent the worst possible condition that could be found in the field. The amount of rectification will depend not only upon the ballast design, but also upon lamp design, and since the same lamp will never repeat from start to start, only a large number of tests will be significant. We agree that there should be some maximum set on the amount of rectification allowable, and we understand that an ASA Committee is now working on this problem.

Since the spread in lamp voltage is a statistical quantity, it is true that most of the lamps will fall within plus or minus 10 voltage range. However, our measurements of our own and of competitors' lamps show that some lamps of all manufacturers reach the voltage limit. For this reason, there are some lamps which on a constant wattage type ballast will be operated at considerably over or under the average wattage. Since mercury lamps are expensive and since proper operation is expected of all lamps, the lamps on the end of the voltage tolerance range cannot be ignored; and for this reason our tests include data covering the entire voltage range. This will not be a problem with the lag ballast which has the desirable property of supply rated watts and lumens over the entire voltage range.

In regard to the use of hard glass outer jackets which

during lamp life evolves hydrogen that causes hard starting, this effect has been overcome by the proper use of getters in the outer jacket, and also by changing to soft glass outer jackets. The soft glass jacket does not evolve hydrogen at a rate high enough to affect lamp operation during the life of the lamp. However, the early lamps made with lime glass did develop a crazing condition on the glass bulb, and we are happy to say that this condition has also been corrected.

When Dr. Rost speaks of the lamp impedance, we believe that he actually means the impedance of an equivalent circuit. Due to the nature of a gas discharge, a subject beyond the scope of this reply, it is incorrect to speak of *lamp* impedance. The reasons are, first, that the electrical properties of the lamp depend upon the type of ballast used, whether a resistance, inductance, or capacitance. And second, the relation between the lamp voltage and lamp current are non-linear. These two factors make it impossible to speak of a value of lamp impedance. It is possible, however, to *simulate* gas discharge characteristics by means of an equivalent circuit which usually consists of a resistance or somewhat more accurately, a resistance in series with some inductive reactance. It is possible to speak of the impedance of this equivalent circuit, but it is not correct to correlate any part of that circuit with the mechanism of the gas discharge. An excellent discussion, by the way, of discharge equivalent circuits has been written by C. Zwikker: "The Equivalent Circuit of a Gas Discharge Lamp," *Philips Technical Review*, Vol. 15, No. 6, pp. 161-168. It is the impedance of the equivalent circuit that Dr. Rost apparently means.

In answer to Dr. Rost's specific questions, the scales in Fig. 5 are the same for both types of ballasts. The open circuit voltages of the two ballasts have already been discussed. The primary voltage was 115 volts for both ballasts with the 115-volt tap being used on the lag ballast, while the primary rating of the constant wattage ballast was 100 volts to 130 volts.

In answer to Mr. Burns' question in regard to whether the crest factor of the current is more important during starting than during operating, we do not have specific data and can only reply that it is important in both cases and would depend upon the number of starts the lamps receive during their life. Until American Standard specifications are written, we are recommending a maximum current crest factor of 1.7 for both starting and operating conditions.

We feel to some extent Mr. Clark has misinterpreted the purposes of our paper. It is true, as he points out, that changes in primary voltage will greatly affect lamp operation depending upon the type of ballast used. We feel that it is the purpose of the lamp manufacturers to show how, with the different types of ballasts, lamp operation can be affected if these variables occur. It is outside the realm of the lamp manufacturer to control the conditions under which his lamps are operated, and we can only point out how various conditions affect our lamps. Once this information is published, then the user will be able to determine whether or not the lamps are being properly operated.

We are glad to know of Mr. Wyatt's experience with the life of mercury lamps on constant wattage ballasts. We too have found that mercury lamp life does not seem to be shortened by this type of ballast. In regard to lumen maintenance, we would like to point out that we believe that mercury lamps should be photometered under the most careful and accurate conditions possible. Before we add Mr. Wyatt's lumen maintenance to our data, we would like to know by what method he photometered the lamps and in what intervals the lamps were photometered.

As stated in our reply to Mr. Clark's discussion, we cannot run our life tests with varying supply voltages because by doing so we would introduce a new variable in the test, and we would be unable to determine whether the varying line voltage or the type of ballast was producing the life results. We do agree, however, that service tests are very important, and these can always be used to supplement controlled life tests.

In answer to Mr. Till's question regarding our testing of ballasts having crest factors between 1.7 and 2.1, we have not done this although we agree that such data would be very desirable. It is impossible for us to say quantitively how much better a ballast having a lamp current crest factor of 1.7 is than one having a value of 1.85. On the basis of our testing so far, we would say that the closer the lamp current wave shape approaches a sine wave the better will be the lamp performance. We realize that the ballast and lamp manufacturers will have to compromise at some value higher than 1.41, and we believe that this is properly the subject of an ASA Committee. Until such a committee makes a recommendation, we are suggesting a limit of 1.7 for best lamp performance.

Mr. Kronmiller's questions have been answered in the general statements made at the beginning of this reply.

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Effects of Nearby Walks and Concrete Areas On Indoor Natural Lighting

By BOB H. REED

Walks and terraces of concrete or similar highly reflective materials are, as a rule, most beneficial to indoor lighting if they are located no closer than 10 feet from the building and no farther away from it than 40 feet.

With the recent completion of a new and larger model testing laboratory[1] and the development of suitable testing methods[2] at the Texas Engineering Experiment Station, it has become feasible to extend earlier studies of building shapes[3] to include a substantial investigation of the landscape environment. In this investigation of the landscape, as explained in a previous writing from the Texas Engineering Experiment Station,[2] a building and its immediate outdoor surroundings are considered a single design unit from a lighting point of view, which may include an almost unlimited number of potential variables. The sky is considered the sole source of illumination (apart from the ground, which is considered a design variable — a reflective surface). It is standardized by means of the artificial sky.[1]

With the sole source of illumination standardized and held constant under the artificial sky, any one or more design variables in a building or landscape may be studied independently of all others by means of scale models.

This article covers the first of a series of studies of the effects of landscape elements and nearby structures on natural lighting within buildings and deals specifically with walks and other concrete areas near them. The items to be studied in forthcoming work include trees, hedges, screens, and nearby buildings.

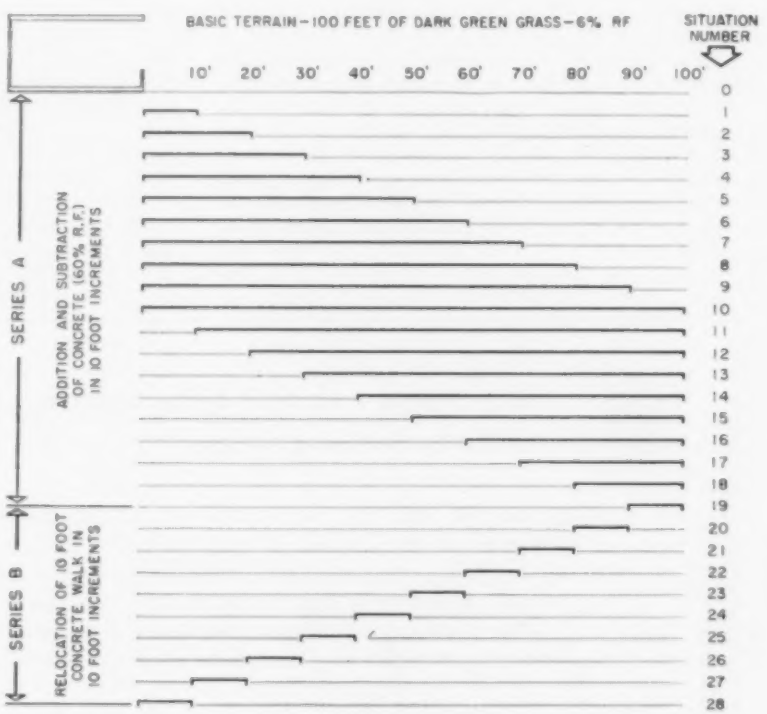
Procedure

A typical one-story workroom (a school classroom or office for example) was used in this study as a reference structure in which illumination measurements were made. The typical workroom was considered to be 24 feet wide, 30 feet long, and 12 feet high from floor to ceiling. Typical reflection factors of 40, 60, and 80 per cent for floor, walls, and ceiling respectively were used in the workroom model. The model was fixed in position adjacent to and facing a 100-foot-deep model terrain which was divided into 10-foot increments. A basic terrain with a reflection factor of 6 per cent, representing dark green grass, was used. All model work was done at a scale of $\frac{3}{4}'' = 1'\,0''$.

The workroom model remained unchanged throughout a complete set of tests. However, four different combinations of fenestration and overhang were used. This was to determine if there would be any substantial difference in the effects of the concrete areas being studied as a result of these fenestration-overhang combinations.

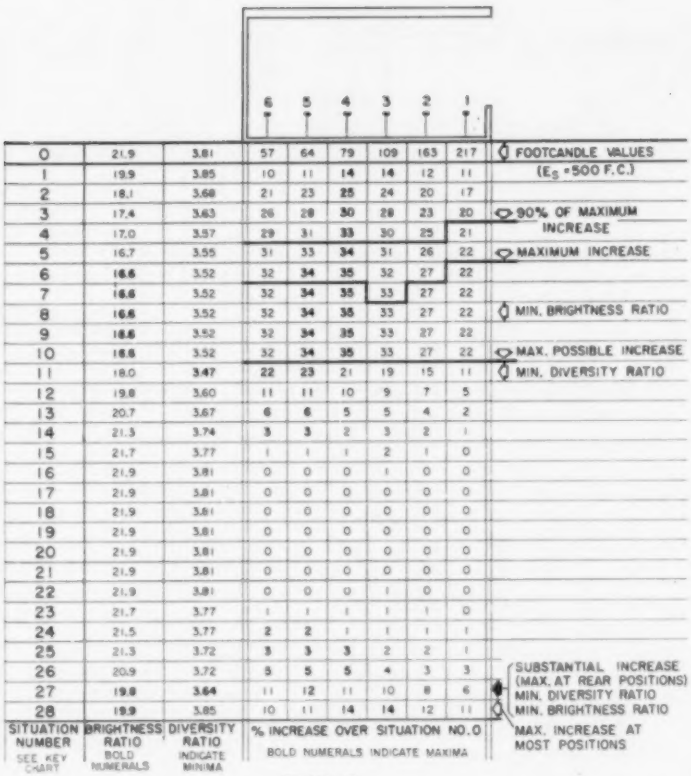
A complete set of tests (29 tests in all) consisted of a "0" or reference test, using only the basic green grass terrain, and 28 other tests involving different amounts of concrete at different locations. See Key Chart.

These tests were divided into two separate series, one dealing with the addition and subtraction of concrete



Key Chart

AUTHOR: Associate Research Architect, Texas Engineering Experiment Station, Texas A. & M. College System, College Station, Texas.



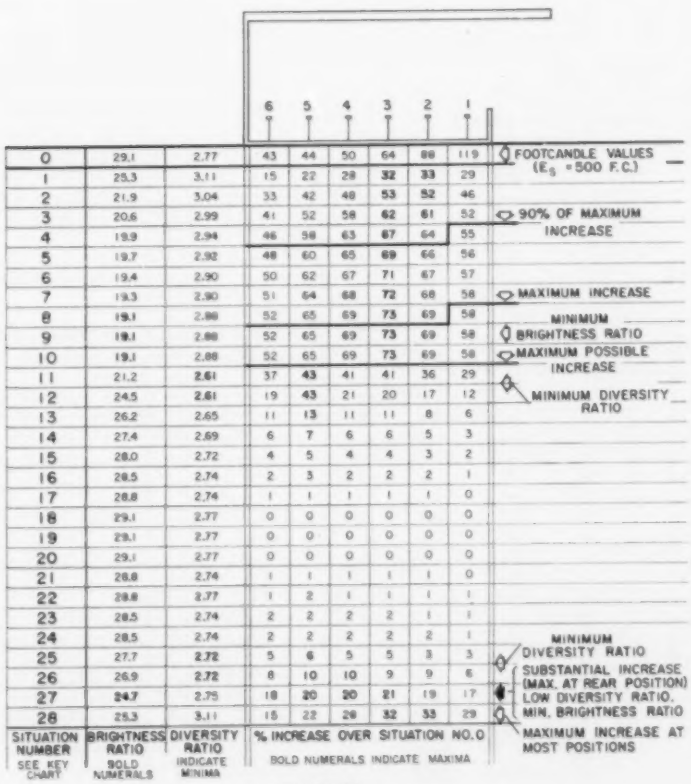
SITUATION NUMBER (SEE KEY CHART)	BRIGHTNESS RATIO (BOLD NUMERALS)	DIVERSITY RATIO (INDICATE MINIMA)	% INCREASE OVER SITUATION NO. 0 — 6	5	4	3	2	1	
0	21.9	3.81	57	64	79	109	163	217	FOOTCANDLE VALUES (E_s = 500 F.C.)
1	19.9	3.85	10	11	14	14	12	11	
2	18.1	3.68	21	23	25	24	20	17	
3	17.4	3.63	26	28	30	28	23	20	90% OF MAXIMUM INCREASE
4	17.0	3.57	29	31	33	30	25	21	
5	16.7	3.55	31	33	34	31	26	22	MAXIMUM INCREASE
6	16.6	3.52	32	34	35	32	27	22	
7	16.6	3.52	32	34	35	33	27	22	
8	16.6	3.52	32	34	35	33	27	22	MIN. BRIGHTNESS RATIO
9	16.6	3.52	32	34	35	33	27	22	
10	16.6	3.52	32	34	35	33	27	22	MAX. POSSIBLE INCREASE
11	18.0	3.47	22	23	21	19	15	11	MIN. DIVERSITY RATIO
12	19.8	3.60	11	11	10	9	7	5	
13	20.7	3.67	6	6	5	5	4	2	
14	21.3	3.74	3	3	2	3	2	1	
15	21.7	3.77	1	1	1	2	1	0	
16	21.9	3.81	0	0	0	1	0	0	
17	21.9	3.81	0	0	0	0	0	0	
18	21.9	3.81	0	0	0	0	0	0	
19	21.9	3.81	0	0	0	0	0	0	
20	21.9	3.81	0	0	0	0	0	0	
21	21.9	3.81	0	0	0	0	0	0	
22	21.9	3.81	0	0	0	1	0	0	
23	21.7	3.77	1	1	1	1	1	0	
24	21.5	3.77	2	2	1	1	1	1	
25	21.3	3.72	3	3	3	2	2	1	
26	20.9	3.72	5	5	5	4	3	3	SUBSTANTIAL INCREASE (MAX. AT REAR POSITIONS)
27	19.8	3.64	11	12	11	10	8	6	MIN. DIVERSITY RATIO
28	19.9	3.85	10	11	14	14	12	11	MIN. BRIGHTNESS RATIO

BOLD NUMERALS INDICATE MAXIMA

MAX. INCREASE AT MOST POSITIONS

SERIES A — SERIES B

Table I



SITUATION NUMBER (SEE KEY CHART)	BRIGHTNESS RATIO (BOLD NUMERALS)	DIVERSITY RATIO (INDICATE MINIMA)	% INCREASE OVER SITUATION NO. 0 — 6	5	4	3	2	1	
0	29.1	2.77	43	44	50	64	88	119	FOOTCANDLE VALUES (E_s = 500 F.C.)
1	25.3	3.11	15	22	28	32	33	29	
2	21.9	3.04	33	42	48	53	52	46	
3	20.6	2.99	41	52	58	62	61	52	90% OF MAXIMUM INCREASE
4	19.9	2.94	46	58	63	67	64	55	
5	19.7	2.92	48	60	65	69	66	56	
6	19.4	2.90	50	62	67	71	67	57	
7	19.3	2.90	51	64	68	72	68	58	MAXIMUM INCREASE
8	19.1	2.88	52	65	69	73	69	58	MINIMUM
9	19.1	2.88	52	65	69	73	69	58	BRIGHTNESS RATIO
10	19.1	2.88	52	65	69	73	69	58	MAXIMUM POSSIBLE INCREASE
11	21.2	2.61	37	43	41	41	36	29	
12	24.5	2.61	19	43	21	20	17	12	MINIMUM DIVERSITY RATIO
13	26.2	2.65	11	13	11	11	8	6	
14	27.4	2.69	6	7	6	6	5	3	
15	28.0	2.72	4	5	4	4	3	2	
16	28.5	2.74	2	3	2	2	2	1	
17	28.8	2.74	1	1	1	1	1	0	
18	29.1	2.77	0	0	0	0	0	0	
19	29.1	2.77	0	0	0	0	0	0	
20	29.1	2.77	0	0	0	0	0	0	
21	28.8	2.74	1	1	1	1	1	0	
22	28.8	2.77	1	2	1	1	1	1	
23	28.5	2.74	2	2	2	2	1	1	
24	28.5	2.74	2	2	2	2	2	1	
25	27.7	2.72	5	6	5	5	3	3	MINIMUM DIVERSITY RATIO
26	26.9	2.72	8	10	10	9	9	6	SUBSTANTIAL INCREASE (MAX. AT REAR POSITION)
27	24.7	2.75	18	20	20	21	19	17	LOW DIVERSITY RATIO.
28	25.3	3.11	15	22	28	32	33	29	MIN. BRIGHTNESS RATIO

BOLD NUMERALS INDICATE MAXIMA

MAXIMUM INCREASE AT MOST POSITIONS

SERIES A — SERIES B

Table II

in 10-foot increments, and the other dealing with the relocation of a 10-foot concrete walks in 10-foot increments. See Key Chart.

For each test a set of 6 illumination readings were taken inside the model as shown on various diagrams in this report. By comparing these illumination readings for any test (from 1-28) with those of test 0, it is possible to ascertain increases in level, changes in distribution, and changes in brightness as a result of the addition of concrete areas to the basic terrain.

Results

Tables I-IV contain the data collected for each of the fenestration-overhang combinations and an analysis of the comparisons of the tests. The top row of numerals (for situation 0) under the cross section diagram are adjusted footcandles values on the basis of an overcast sky of such intensity as to produce an unobstructed vertical surface $(E_s)^2$ level of 500 footcandles, not including light reflected from the ground. The remainder of the numerals in columns under the cross section diagram (situation 1-28) are calculated per cent increases in intensity over situation 0. The bold numerals indicate maximum increases for each situation. This is to show when maximum increase occurs farthest from the window, thereby producing minimum diversity. Diversity ratios for each situation were calculated by dividing the level at position 1 by that at position 6. Brightness ratios for each situation were calculated and represent the ratio of the highest brightness to the lowest task brightness. The highest brightness was taken to be the sky as seen through open windows and was given an assumed value of 1000 footlamberts, a value frequently assumed in conjunction with a vertical surface illumination of 500 footcandles. This assumes the use of window sill arrangements which shield from view brightly sunlit concrete and other light colored areas of terrain which might be brighter than the sky. The lowest task brightness was calculated by multiplying the lowest footcandle value (position No. 6) by an assumed task reflection factor of 80 per cent.

An analysis of the comparison of the tests appears in the right-hand column of each of the four tables showing for Series A:

(1) Situation at which maximum possible increase in intensity occurs (this is always situation No. 10 — 100 feet of concrete — see Key Chart).

(2) Situation at which maximum increase is first attained.

(3) Situation at which 90 per cent of maximum increase is attained.

(4) Situation at which minimum brightness ratio occurs.

(5) Situation at which minimum diversity ratio occurs.

And for Series B:

(1) Situation at which maximum increase in illumination occurs at all or most positions.

(2) Situation at which minimum brightness ratio occurs.

(3) Situation at which minimum diversity ratio occurs.

(4) Situation at which optimum combined conditions occur (substantial increase in illumination, minimum or near minimum brightness and diversity ratios).

It will be noticed that maximum illumination increase and minimum brightness and diversity ratios seldom occurred simultaneously.

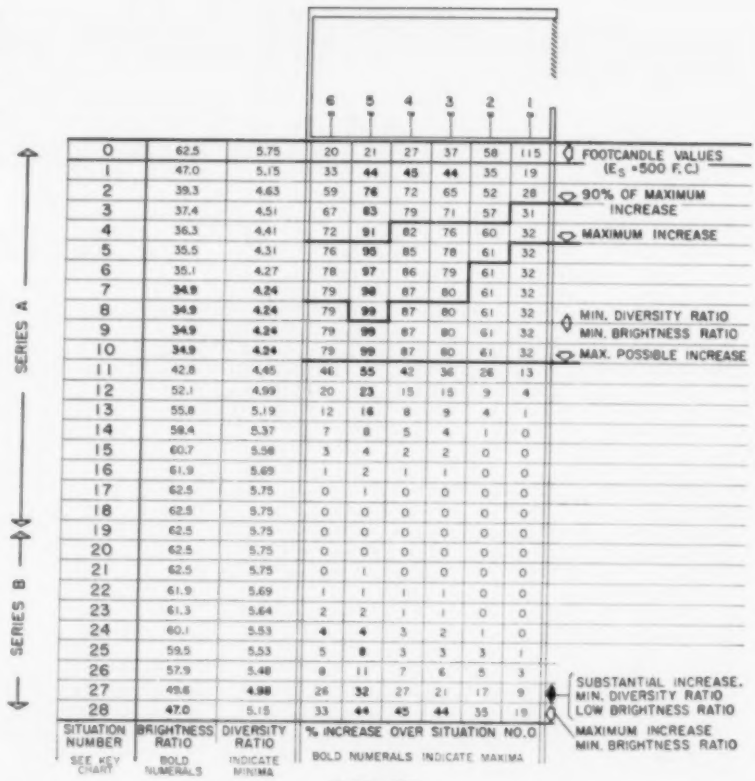
Discussion

A comparison of the four tables will quickly reveal that all four fenestration-overhang arrangements were very similar in their utilization of the light reflected into the classroom by the concrete areas. Therefore, a complete discussion of the results of Table I only follows with reference made to the other tables. Concerning Series A:

(1) Maximum possible illumination increase always occurred at situation 10 (maximum addition of concrete — 100 feet).

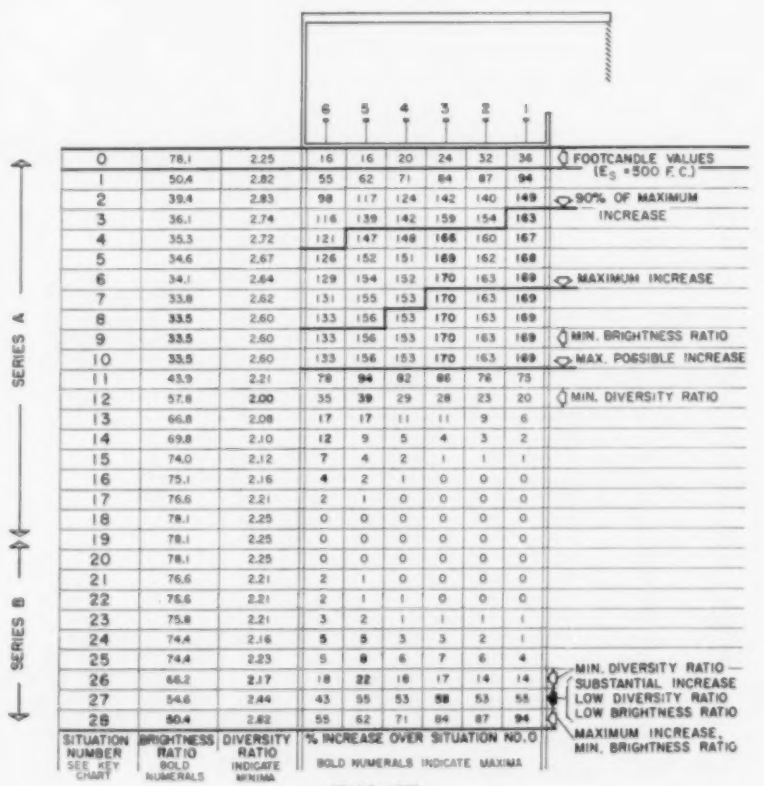
(2) Maximum increase was first attained at about situation 6 (60 feet of concrete added) for most positions. Beyond this distance, no additional illumination increase was realized by the addition of more concrete area. This distance showed a tendency to shift farther out to about 70 to 80 feet in the cases employing overhangs. See Tables II and IV.

(3) Ninety per cent of maximum increase was attained for most positions at about situation 4 (40 feet of concrete added). This distance showed a tendency to shift somewhat closer to the building at about situation 3 — 30 feet of concrete — in cases employing louvers (45-degree louvers with horizontal cut-off).



SITUATION NUMBER (SEE KEY CHART)	BRIGHTNESS RATIO (BOLD NUMERALS)	DIVERSITY RATIO (INDICATE MINIMA)	% INCREASE OVER SITUATION NO. 0 (BOLD NUMERALS INDICATE MAXIMA)					
			6	5	4	3	2	1
0	62.5	5.75	20	21	27	37	58	115
1	47.0	5.15	33	**44**	**45**	**44**	35	19
2	39.3	4.63	59	**76**	72	65	52	28
3	37.4	4.51	67	**83**	79	71	57	31
4	36.3	4.41	72	**91**	82	76	60	32
5	35.5	4.31	76	**98**	85	78	61	32
6	35.1	4.27	78	**97**	86	79	61	32
7	**34.9**	**4.24**	79	**98**	87	80	61	32
8	**34.9**	**4.24**	79	**99**	87	80	61	32
9	**34.9**	**4.24**	79	**99**	87	80	61	32
10	**34.9**	**4.24**	79	**99**	87	80	61	32
11	42.8	4.45	46	**55**	42	36	26	13
12	52.1	4.99	20	**23**	15	15	9	4
13	55.8	5.19	12	**16**	8	9	4	1
14	58.4	5.37	7	**8**	5	4	1	0
15	60.7	5.58	3	4	2	2	0	0
16	61.9	5.69	1	2	1	1	0	0
17	62.5	5.75	0	1	0	0	0	0
18	62.5	5.75	0	0	0	0	0	0
19	62.5	5.75	0	0	0	0	0	0
20	62.5	5.75	0	0	0	0	0	0
21	62.5	5.75	0	1	0	0	0	0
22	61.9	5.69	1	1	1	1	0	0
23	61.3	5.64	2	2	1	1	0	0
24	60.1	5.53	**4**	**4**	3	2	1	0
25	59.5	5.53	5	**8**	3	3	3	1
26	57.9	5.48	8	11	7	6	5	3
27	49.6	**4.98**	26	**32**	27	21	17	9
28	**47.0**	5.15	33	**44**	**45**	**44**	35	19

Table III



SITUATION NUMBER (SEE KEY CHART)	BRIGHTNESS RATIO (BOLD NUMERALS)	DIVERSITY RATIO (INDICATE MINIMA)	% INCREASE OVER SITUATION NO. 0 (BOLD NUMERALS INDICATE MAXIMA)					
			6	5	4	3	2	1
0	78.1	2.25	16	16	20	24	32	36
1	50.4	2.82	55	62	71	84	87	**94**
2	39.4	2.83	98	117	124	142	140	**149**
3	36.1	2.74	116	139	142	159	154	**163**
4	35.3	2.72	121	147	148	**166**	160	**167**
5	34.6	2.67	126	152	151	**169**	162	**168**
6	34.1	2.64	129	154	152	**170**	163	**169**
7	33.8	2.62	131	155	153	**170**	163	**169**
8	**33.5**	2.60	133	156	153	**170**	163	**169**
9	**33.5**	2.60	133	156	153	**170**	163	**169**
10	**33.5**	2.60	133	156	153	**170**	163	**169**
11	43.9	2.21	78	**94**	82	98	78	75
12	57.8	**2.00**	35	**39**	29	28	23	20
13	66.8	2.08	17	17	11	11	9	6
14	69.8	2.10	**12**	9	5	4	3	2
15	74.0	2.12	7	4	2	1	1	1
16	75.1	2.16	**4**	2	1	0	0	0
17	76.6	2.21	2	1	0	0	0	0
18	78.1	2.25	0	0	0	0	0	0
19	78.1	2.25	0	0	0	0	0	0
20	78.1	2.25	0	0	0	0	0	0
21	76.6	2.21	2	1	0	0	0	0
22	75.6	2.21	2	1	1	0	0	0
23	75.8	2.21	3	2	1	1	1	1
24	74.4	2.16	**5**	**5**	3	3	2	1
25	74.4	2.23	5	**8**	6	7	6	4
26	66.2	2.17	18	**22**	16	17	14	14
27	54.6	2.44	43	55	53	**58**	53	55
28	**50.4**	2.82	55	62	71	84	87	**94**

Table IV

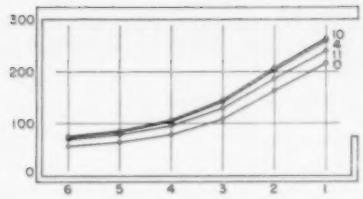


Figure 1. Illumination levels plotted for situations 10, 4, 11 and 0.

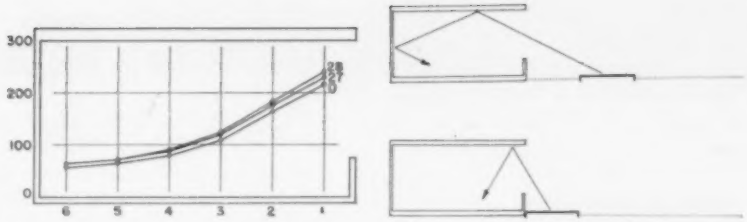


Figure 2. Illumination levels plotted for situations 27, 38 and 0. Drawings at right show situation 27 at top and situation 28 below.

(4) Minimum brightness ratio, of course, occurred simultaneously with a maximum illumination increase at position 6 in the classroom. In Table I it occurs with situations 6-10. In other tables it is similar, occurring with situations 7-10 or 8-10.

(5) Minimum diversity ratio occurred at situation 11. The removal of the first strip of concrete nearest the building had a much greater light-decreasing effect on positions near the windows than on positions remote from the windows which resulted in a lower diversity ratio. This can be seen more clearly in Fig. 1 on which footcandle curves are plotted for situations 10, 4, 11 and 0.

The point of minimum diversity ratio is similar in other tables (situation 11 or 12) with exception of Table III in which it occurred simultaneously with the point of minimum brightness ratio (situations 7-10).

Concerning Series B:

(1) Maximum increase at all or most positions occurred at situation 28 (10-foot strip of concrete adjacent to the building) in all four tables.

(2) Minimum brightness ratio and minimum diversity ratio, however, occurred at situation 27 with variations from situations 26-28 in other tables.

(3) Optimum combined conditions (substantial increase in illumination at most points, plus minimum or near minimum brightness and diversity ratios) seemed to occur at situation 27 in all four tables.

This can be seen more clearly in Fig. 2, on which are plotted footcandle curves for situations 27, 28 and 0. Notice that curves 27 and 28 show substantially the same effect at position 6 while showing widely different effects at position 1.

The sketches accompanying Fig. 2 show how the first strip of concrete adjacent to the building (situation 28) contributes its maximum effect at positions near the windows, while concrete strips farther from the building (situation 27) contribute maximum effects at positions remote from the windows. This explains the difference in diversity ratios.

Fig. 3 and the accompanying sketches show why this effect of changing the diversity ratio is not as great when using an overhang. The overhang apparently reflects ground light coming from areas farther from the building to positions near the windows, preventing such a large change in diversity ratios from situation 28 to situation 27. It should be pointed out, however, that the classroom with the overhang has a lower diversity ratio in any case because of the effect of the overhang on direct sky light entering the windows. It reduces direct sky light a greater proportion at positions near the windows than it does at positions removed from the windows, thereby resulting in a lower diversity ratio than the same classroom without the overhang although the levels are somewhat lower.

Conclusions

It is felt that several useful conclusions can be generalized as a result of this study. They are as follows:

(1) Concrete walk and terrace locations will have a pronounced effect on the quantity and distribution of natural light in a building, in many instances improving it.

(2) Substantial improvement in both quantity and distribution, and therefore in brightness ratios, can be realized with optimum location of concrete areas.

(3) Substantial and useful increases in natural illumination within a building may be gained from highly reflective terrain in somewhat limited areas beyond the building.

(a) Virtually no gain in quantity of natural light is realized by using highly reflective surfaces beyond 60-70 feet from a one-story building.

(b) Furthermore, only negligible gain is realized by the use of such surfaces beyond approximately 40 feet from the building. (Ninety per cent of the quantity gained with the use of 60 or even 100 feet of highly reflective surface is gained within the first 40 feet beyond the buildings.)

Quantity gains and brightness ratio improvements remain substantial, and diversity ratios are improved considerably when the first 10 feet or so adjacent to the building is not treated with a highly reflective surface since this area tends to have maximum effect on positions in the building nearest the

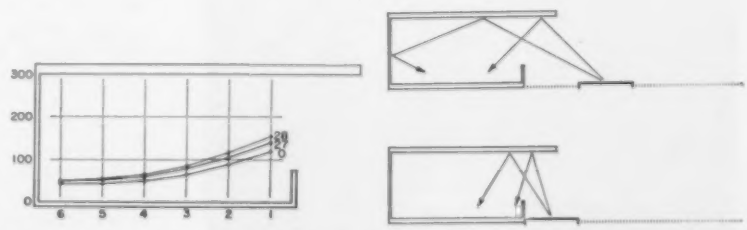


Figure 3. Effect of changing diversity ratio is not as great when using an overhang. Drawings at right show situation 27 at top and situation 28 below.

windows. This would seem to suggest that large areas of concrete or other highly reflective surfaces such as terraces should not be directly adjacent to the building (preferably at least 10 feet away) for optimum effects on natural lighting but should be included within the first 40 feet.

(4) Optimum location of a typical 10-foot concrete walk can be generalized as follows:

(a) The closer the walk is to the building, the greater the average quantity gain will be inside the building, but the greater the diversity ratio will be.

(b) The farther the walk is from the building, the lower the diversity ratio will be but the lower the quantity gain will be.

(c) The walk, as with a terrace should not be directly adjacent to the building (preferably at least 10 feet away) but should be included within the first 30 feet for optimum effects on natural lighting since it is a much smaller area than would be a terrace.

(5) Generally, light reflected from that area of terrain approximately 10 to 40 feet from a one-story building makes an important contribution to positions inside the building farthest from the windows. Light reflected from that area of terrain directly adjacent to the building (approximately 10 feet) contributes mostly to positions near the windows.

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Lighting Compatible with Architecture For Now and the Future

St. Roch Parish Church in Quebec, Que., has Renaissance architecture, with a Roman vault, Greek center transept, and Gothic influence in the columns, groining and cross-ribbing. In the design of the re-lighting system, a prototype was found in an installation at St. Sacrament Church, where a lighting system was integrated with the architecture. Church renovators Barsetti et Frère, electrical contractor Marcel Lapointe, and the Canon of St. Roch visited St. Sacrament, and decided upon a similar system, with these conditions: (1) retention of the existing ornamental lanterns and integration of the lighting with them; (2) a somewhat higher illumination level than the 11 ft-c in St. Sacrament; (3) provision for replacing the lanterns in the future, at minimum expense.

First on the program was a complete overhaul of the lanterns — glass washed, reflectors and lamps replaced. This raised the average illumination from 1.2 ft-c to 4.2 ft-c. The sixteen lanterns, mounted at a height of 30 feet in the 65-foot ceiling, use one 150-watt lamp and eight 60-watt lamps each.

The new lighting system (shown at left, with lanterns turned off) consists of flush-mounted, top-servicing, prismatic reflector-lens luminaires, arranged in the vault of the ceiling to provide sufficient coverage of illumination and to allow replacement of the lanterns in the future without change in the present installation. A total of 115 units, using 300- and 200-watt lamps, are located in chancel, nave, transepts under balconies, and in the choir and organ loft. When the lanterns are replaced, 32 more recessed units will provide, with the present installation, the same illumination level. The recessed fixtures provide average level of 8.4 ft-c, making, together with the lanterns, a total of nearly 13 ft-c.

Altar lighting was designed by M. Lapointe who specified PAR 38 lamps in swivel holders.

Reflectances in the church are: ivory ceiling and walls, 60%; pews, 10%; floor, 65%.

This installation was entered by H. John Ward, of the Holophane Co., Ltd., Montreal, in the Montreal Section's 1956 contest for My Most Interesting Lighting Job; and also won third prize for Valère Marcoux, Northern Electric Co., in the Quebec Chapter's 1956 MMILJ contest.

Relation of Changes in Pupil Size To Visual Discomfort

By JACK M. FUGATE
GLENN A. FRY

NATURE HAS a way of producing comfortable lighting. The source is high out of the field of view. The diffusion is good with a great luminous vault of blue sky to soften the shadows and reduce the contrast. However, nature at times has uncomfortable lighting too. The sun is low, the sand is too bright, the water is a sheet of flame, the snow dazzles. Man ducks his head down, squints his eyes, tears flow, and he peeks out of a nearly closed eye.

Man's lighting has often been uncomfortable also. How real is this feeling of discomfort? This study was undertaken in order to help pin down this feeling and add to man's knowledge of discomfort glare, which ultimately will help lighting designers limit the brightness of luminaires and daylighting fenestration to produce comfortable lighting installations. We have investigated the role played by the constriction of the pupil of the human eye associated with brief exposures of light in producing discomfort. This has certain advantages over using continuous exposure:

1. The results can be correlated with the subjective data which have already been made available.
2. The pupillary response to brief exposures of light can be evaluated in terms of changes in pupil size. In the case of steady stimulation one can measure only the absolute size of the pupil and since this is determined by so many factors it would be difficult to correlate absolute size with the experience of discomfort. For example, the actions of the sphincter and the dilator fibers (which control the closing and opening of the iris) oppose each other and the size of the pupil is not therefore a measure of the amount of tension in the iris. In the case of a continuous exposure and a non-uniform distribution of light on the retina, an eye movement would produce a shift of the distribution of light on the retina and this would affect in a complicated way the output of nerve impulses to the iris.
3. The use of brief exposures of light permits the measurement of blink reaction times and, as will be obvious later, this information is more useful than the blink rate which is the only thing that can be measured with steady exposure.

The test apparatus has been designed to present various light stimuli to the left eye while the right eye is kept in darkness. At the same time provision has been made for recording the changes in the consensual pupillary responses of the right eye by means of infrared photography. This arrangement prevents interference between the stimulating and the recording equipment. The consensual response in the right eye parallels the direct response in the left eye so that a record of either one is adequate for the purpose of this investigation. This setup is shown in Figs. 1 and 2 and described in detail in Appendix A.

The stimuli used in this study were in the form of a momentarily exposed round area of brightness against an illuminated background. As shown in Fig. 3 the stimuli presented to the left eye include a disk-shaped adaptation field 51 degrees in diameter which is exposed continuously, and a one-second momentary stimulus which is superimposed on the adaptation stimulus and centered with respect to it.

By varying the brightness of a brief exposure of light, presented in the form of a small disk on a less bright background, one can determine the borderline between comfort and discomfort (BCD). Luckiesh and Guth have done this for momentary stimuli of various sizes and for various background brightnesses.

A limited number of measurements of this sort have been made in the present investigation. The BCD levels found in the present study are slightly higher than those found by Luckiesh and Guth, but this can be accounted for in part by the fact that in our study the stimuli were presented to one eye. Also, the criteria used by our subjects may have differed from those used by the subjects of Luckiesh and Guth. The detailed procedure followed to obtain the pupillary responses to brief exposures of light of various sizes and brightnesses presented on backgrounds of different brightnesses are described in Appendix B.

The results show that the BCD level is three or

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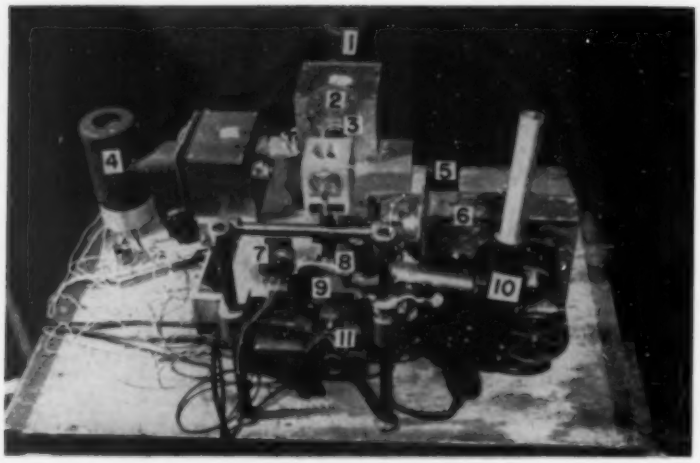

Figure 1. Photograph of test apparatus.

1—Momentary stimulus B.
2—Desk with detents and apertures controlling diameter of momentary stimulus.
3—Neutral density filter controlling brightness of momentary stimulus.
4—Adapting stimulus source A.
5—Fixation point source.
6—Camera for recording changes in pupil diameter.
7—Shutter.
8—Head rest.
9—Eye piece.
10—Infrared source illuminating iris of right eye.
11—Bite board.

more log units above the threshold of the pupillary response and at the BCD level the pupil undergoes a constriction of the order of 1.5mm. The actual amount of pupillary constriction at the BCD level varies with the size of the momentary stimulus.

This fact probably means that the distribution of the activity among the motor units of the sphincter muscle which controls the closing of the iris varies with the distribution of the light on the retina, and that one type of distribution may be more effective than another in producing discomfort, even though the amount of the constriction may be the same in both cases. This possibility will have to be explored in subsequent research.

Paralysis of the iris of one eye by means of the drug homatropine produced no significant change in the BCD level of the other eye, but paralysis of both irises at the same time greatly increased the threshold of discomfort in all but one of the subjects. These facts indicate that in these cases the contraction of the iris is one of the factors contributing to discomfort. Homatropine also paralyzes the ciliary muscle which controls the crystalline lens of the eye, but since the stimulus to accommodation was kept constant at infinity, the fact that the ciliary muscle was paralyzed is of no importance in interpreting the results of this experiment.

All of the subjects found it quite intolerable under paralysis of both irises to walk out into the open and face the sky. The subjective experience encountered in this situation is characterized by tenseness and an uncontrollable desire to blink. It differs from the type of discomfort encountered at the BCD level when the irises are normal.

An analysis of the objective responses to brief exposures of light encountered at different brightness levels also indicates that several types of response mechanisms are operating. It has been possible to determine a level of brightness which we have called the threshold of involuntary blinking, (TIB). At this level the subjects find it impossible to suppress involuntary blinking.

The TIB level is affected by paralysis of the irises. This proves that in subjects with normal irises stimulation of the fifth nerve endings in the iris, by constriction of the sphincter muscle of the iris, contributes to the pool of excitation which leads eventually to irrepressible blinking.

Appendix A — Apparatus and Its Operation

The apparatus is illustrated schematically by Fig. 2. The elements represented by solid lines lie in a horizontal plane through the centers of the entrance pupils of the two eyes. The elements represented by the dotted lines lie in a plane which is rotated 15 degrees downward around the axis xx' so that the mirror M_2 does not occlude the right eye's view of L_{15}.

A photograph of this apparatus is shown in Fig. 1. In In order to make the diagram in Fig. 2 conform to Fig. 1, all of the elements on the line between S_2 and L_{12} should be rotated 180 degrees around a point at the center of P.

The head and eyes of the subject are positioned by means of a biting board and a forehead rest (see Fig. 1) so that the center of the pupil of the left eye falls at point E and the center of the pupil of the right eye is conjugate with A_5, M_1, L_{15} and all of the dotted elements can be displaced sideways to provide for variation in the interpupillary distance from subject to subject.

The eye piece lenses L_6 and L_7 permit the left eye to view in the focal plane of the eyepiece an image of aperture A_1 formed by the collimating lens L_4 and objective lens L_5; and/or an image of A_4 formed by the collimating lens L_{12} and objective lens L_5. In the case of aperture A_1, the light is transmitted by the beam splitter P; in the case of A_4 the light is reflected by the hypotenuse of the beam splitter.

Aperture A_1 is one of many apertures that are contained in a metal disk which is positioned by a detent. The areas

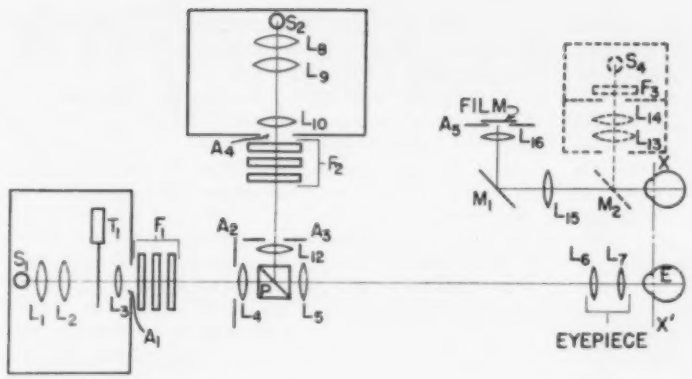

Figure 2. Schematic diagram of test apparatus.

of these apertures vary in one-half log unit steps. They subtend visual angles to the left eye ranging from 1½ degrees to 51 degrees. Aperture A_4 is a fixed aperture and subtends a visual angle of 51 degrees. Lenses L_1 and L_2 form a magnified image of the ribbon filament source S_1 in the plane of A_1. This image completely fills the largest aperture available. Lens L_3 located in the plane of A_1 forms an image of L_2 in the plane of A_2 which is located in the same plane as L_4. Lenses L_5, L_6 and L_7 form an image of A_2 in the plane of the entrance pupil E.

The flux density in the focal plane of the eyepiece is uniform, but it is not uniform in the entrance pupil of the eye. Therefore, in computing retinal illumination *(E)* it is necessary to base it on the total number of lumens *(F)* in the beam entering the eye and the solid angle (ω) subtended by the image of A_1 or A_4 in the focal plane of the eyepiece. A troland is the unit of retinal illumination; one troland equals 2.5 times the product of the brightness in millilamberts and the square of the pupillary diameter measured in millimeters. When retinal illumination is expressed in trolands and solid angle in steradians,

$$E = 10^6 \, F/\omega.$$

Two filter holders are constructed so as to position three neutral density filters in front of apertures A_1 and A_4. Whenever less than three filters are used, an equivalent thickness of clear glass with plane faces is put in the filter holder in order to keep the distance of the optical path constant. These filters may be varied in one-half log unit steps. The output of the light source S_1 can also be varied by means of a variac; however, in the present study the variac was switched out of the circuit except for the purpose of determining the BCD and the TIB. The rotary solenoid shutter T_1 is positioned immediately behind aperture A_1. When activated T_1 will rotate so as to allow light from S_1 to pass through A_1. The time that T_1 is rotated so as to allow light to pass through A_1 is predetermined by means of an electronic timer. The rotation of T_1 is for all practical purposes noiseless and vibrationless. T_1 is a spring reload type solenoid and automatically resets itself when activation ceases.

The right and left margins of the iris of the right eye are illuminated by a rectangular patch of infrared light, 5mm by 11mm, which spans the pupil and which is the image of S_4 formed by condensing lenses L_{14} and L_{13} after reflection by M_2. F_3 is an infrared filter.

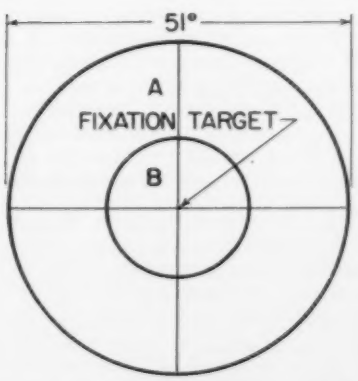

Figure 3. Stimulus pattern presented to the left eye, adapting stimulus A and momentary stimulus B. The diameter of B varied from 1.5° to 51°. Fixation and accommodation are controlled by means of a pair of crosshairs in the focal plane of the eyepiece which intersect at the center of the adaptation stimulus.

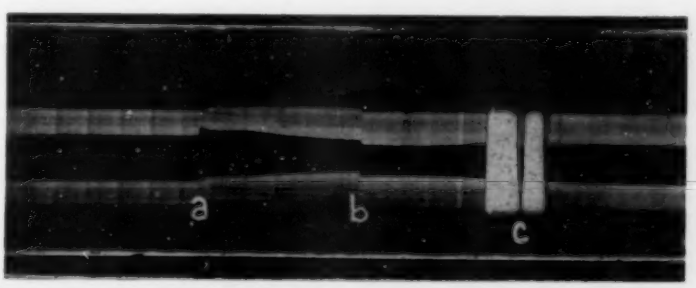

Figure 4. Photographic record of a typical pupil response, with the film moving one inch per second.
a — Onset of momentary stimulus.
b — Cessation of momentary stimulus.
c — Blink.

An image of the iris with unit magnification is formed in the plane of the vertically moving film by collimating lens L_{15}, mirror M_1, and camera lens L_{16}. A_5 is a horizontal slit 0.008 inch wide, directly in front of the moving film. The image of the entrance pupil is centered on the slit. The film travels at a speed of one-quarter inch per second. This gives the camera a resolving power of 0.032 second. The camera is a modification of an Ophthalmograph which uses 35 mm film. The film used was Eastman Spectroscopic safety film Type 1-N.

Mirror M_1 is mounted so that it can rotate around a vertical axis. When shutter T_1 is activated the mirror rotates slightly and when it is deactivated M_1 returns to its original position, thus accurately marking on the film the beginning and end of the stimulus. The rotation is accomplished by modifying a relay so that it will operate as a lever, thus supplying the necessary power and synchronization to rotate the mirror at the proper time. Fig. 4 is a typical film record obtained with the film travelling one inch per second.

Appendix B — Detailed Procedures and Results

Pupillary Responses to Brief Exposures of Light of Various Sizes and Brightnesses Presented on Backgrounds of Different Brightnesses

General — This part of the procedure was designed to provide measurements of pupil responses to brief exposures of light which might be correlated with the data obtained by Luckiesh and Guth[1] on the border line between comfort and discomfort, (BCD). The data obtained by Luckiesh and Guth showing the relation of the BCD brightness to the brightness of the background and the area of the test source are shown in Fig. 5. Their results show that for a given level of background brightness a given per cent increase in brightness of the test source has a greater effect on discomfort than the same per cent increase in area.

Experimental Differences — This experiment duplicated in general, the experiment by Luckiesh and Guth,[1] but varied as follows:

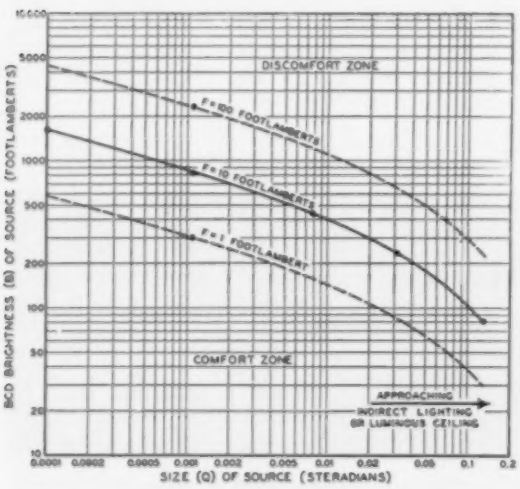

Figure 5. Luckiesh-Guth data for the relationship between BCD brightness (B) and size (Q) of a momentary stimulus located on the line of sight for three surrounding field brightnesses (F).

(1) This experiment is monocular; *i.e.*, the stimuli are presented to the left eye only, and a record is made of the pupil response in the opposite eye.

Luckiesh and Guth made one observation which bears on the problem of whether the BCD is higher with one eye open than with both eyes open. They did not find any significant change in the curves for horizontal displacement of the momentary stimulus source from the point of fixation at the transition point between binocular and monocular perception of the sources. The actual transition point varied from subject to subject, being dependent upon facial configuration, and ranged from approximately 40 to 50 degrees. An examination of individual data revealed no sudden change in BCD brightness which could be attributed to this factor. This observation appears to be at variance with the fact that persons who suffer from high brightness, find some relief by closing one eye.

(2) This experiment used an artificial pupil, the exit pupil of our optical system, of approximately 1½ mm in diameter. Since this is smaller than the smallest possible pupil diameter, the amount of light entering the eye was always the same under a fixed set of experimental conditions regardless of the subject's pupil size. This made it possible to make a direct comparison between subjective responses with a normal pupil and those with a drugged (paralyzed) pupil.

(3) The adapting stimulus, for this experiment, was 51 degrees (focused light) in diameter which is about $^1/_6$ of a hemisphere.

Procedure — For each level of adaptation and for each size of the momentary stimulus an attempt was made to determine the brightness threshold of the pupillary response and to record the suprathreshold responses for various stimuli in the range between the threshold and at least two log units above this threshold. A previous investigation[2] provided the information for determining the range of stimuli needed.

Luckiesh and Guth used three levels of adaptations corresponding to brightnesses of 1, 10, and 100 footlamberts viewed with the natural pupils. We aimed to duplicate these levels by presenting to the left eye stimuli producing the same levels of retinal illumination as was produced on each of the retinas in the Luckiesh-Guth experiment. The retinal illumination produced by 1, 10 and 100 footlamberts in the Luckiesh-Guth experiment were computed as follows: From Reeve's data[3] it was determined that with both eyes open following adaptation to 1, 10 and 100 footlamberts the pupil diameters would be 5.0, 4.0 and 2.8 mm respectively. The following formula was then used for computing the equivalent number of trolands:

$$E = A\,B$$

where E = retinal illumination in trolands,
A = area of the pupil in mm^2, and
B = brightness in c/m^2

The following values were obtained:

1 footlambert ≏ 67.25 trolands
10 footlamberts ≏ 430.3 trolands
100 footlamberts ≏ 2,110.4 trolands

The actual values of retinal illumination for the adaptation stimuli used in our experiment were 71, 450 and 2258 trolands. Therefore the levels of adaptation used by us are nearly equivalent to those used by Luckiesh and Guth.

Procedure — The following procedure was used in this part of the investigation. The subject adapted to the adap-

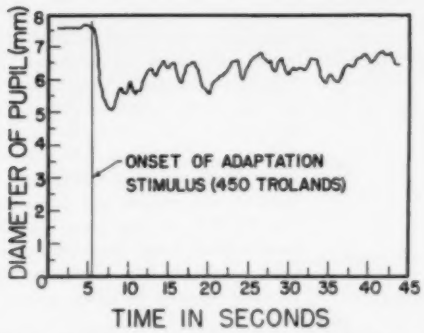

Figure 6. Changes in pupil size which occur during 30 seconds of exposure to an adaptation stimulus. The eye was in darkness prior to exposure of the adaptation stimulus.

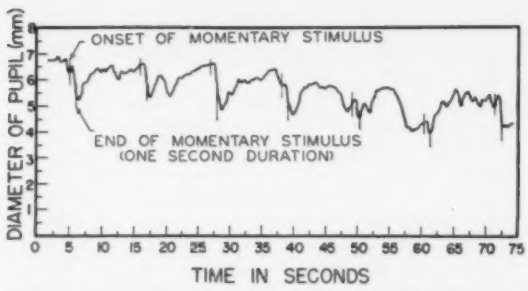

Figure 7. Pupillary responses to a series of seven momentary stimuli spaced 10 seconds apart. Brightness of momentary stimulus equals 1000 trolands; brightness of adaptation stimulus equals 450 trolands; size of momentary stimulus equals 5½°.

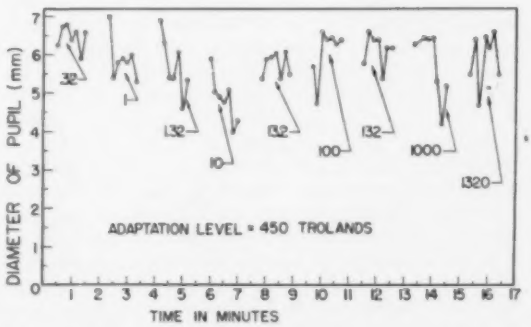

Figure 8. Variations in initial pupil diameter from run to run and from stimulus to stimulus. The retinal illumination in trolands for the momentary stimulus during each run is indicated on the graph.

tation stimulus of 71, 450 or 2258 trolands for 30 seconds, then a one-second momentary stimulus was presented concentric with the subject's fixation point in the center of the adaptation field; this was followed by a nine-second interval during which the subject continued to view the adaptation source and then another one-second flash stimulus followed by a nine-second interval, and so on until seven momentary stimuli had been presented. This constituted a run.

The pupil responses were recorded on a moving film (see Fig. 4) as explained in Appendix A. This film was analyzed with a Bausch and Lomb magnifier which had a built-in scale permitting the diameter of the pupil to be measured to the nearest 0.05 mm. The magnifier was mounted in a specially designed jig. The amount of constriction produced by brief exposure of light was determined by measuring the initial diameter (approximately 0.2 seconds following the onset of the stimulus) and at the peak of the constriction and taking the difference between them.

In case of stimuli in the region of the threshold where a response could not be easily identified the diameter was arbitrarily measured at a point in the record approximately 0.9 second following the onset of the momentary stimulus in order to obtain a measurement that would correspond to the peak of a supra-threshold response. The peak of a response just above the threshold occurred at approximately 0.9 second.

The pupillary responses to the last five of the seven momentary stimuli in each run were measured and averaged. Occasionally the response to the second stimulus was included, if for one of several reasons, the record of the response to one of the last five stimuli could not be used.

Results — It was found that the pupil did not reach and maintain a steady size even after 30 seconds of adaptation but continued to fluctuate. These fluctuations, which occur during a period of 30 seconds of bright adaptation, are illustrated in Fig. 6. Such spontaneous fluctuations in the record make it difficult to interpret the records of responses to momentary stimuli as illustrated in Fig. 7.

In addition to the spontaneous fluctuations which have a period of the order of one to five seconds and which produce unpredictable variations in the initial pupil size from stimulus to stimulus there were also slow systematic changes in the initial pupil size from stimulus to stimulus and run to run, as shown in Fig. 8. The average initial pupil size for the stimuli in a given run would vary from that for the stimuli in another run in the same series of runs as much as 1½ mm to 2½ mm. These variations in the initial pupil size made it necessary to analyze the data in terms of changes in pupil size produced by a brief exposure of light instead of the absolute values of pupil diameter. The actual change in millimeters of pupil diameter produced by a momentary stimulus has been used as the measure of pupillary constriction.

These fluctuations made it necessary to average the results of five successive momentary stimuli in order to obtain a representative response to a given stimulus situation. In the case of a stimulus in the region of the threshold it was possible for one of these spontaneous fluctuations to make the pupil appear to dilate following a brief exposure to light. By averaging algebraically five successive stimuli we could determine whether the average response was significantly different from zero.

The data obtained in this phase of our study are shown in the upper graphs in Fig. 9. In general, the curves have an ogive form. Near the threshold the slope of the curves gradually increases but finally becomes constant and remains constant through at least a three log unit range of momentary stimuli intensities, and then decreases again. As indicated in previous studies[2,4] it finally reaches a constant level.

The levels for the threshold of the pupillary response indicated in Fig. 9 can be compared with the BCD levels in Fig. 5 for stimuli having the same sizes and background brightnesses. The momentary stimuli used in our experi-

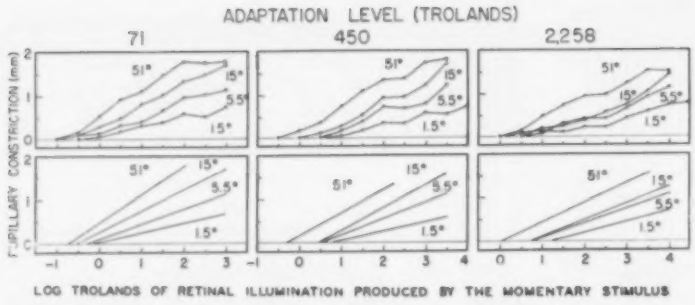

Figure 9. Pupillary responses produced by momentary stimuli of different sizes and brightnesses and at different adaptation levels. Each point in each of the upper graphs represents an average of 25 responses, five for each of five subjects. The curves in each graph represent different diameters of the momentary stimuli. The straight lines in the lower graphs are those which have been fitted to the open points in the upper graphs by the method of least squares.

TABLE I.—Solid Angles Subtended by the Momentary Stimuli.

Diameter (degrees)	Solid Angle (steradians)
1.5	.00057
5.5	.0074
15.	.055
51.	.623

ment, which are 1.5, 5.5, 15 and 51 degrees in diameter, subtend solid angles as indicated in Table I. The pupil sizes for the three adaptation levels (1, 10, and 100 footlamberts) are assumed from Reeve's data to be 5, 4 and 2.8 mm and therefore the retinal illumination for the BCD brightnesses in Fig. 5 for momentary stimuli of different sizes and brightnesses can be computed. These are given in Table II. As derived from Fig. 9 and Table II the threshold for a pupil response is much below the BCD level.

The method of least squares has been used to fit a straight line to the middle portion of each of the curves in each of the upper graphs in Fig. 9. The points used in this operation are indicated as open points in the graphs. The straight lines thus obtained are presented in the lower graphs in Fig. 9. With these graphs it is possible to determine the brightness of a momentary stimulus required to produce a pupil response of a given magnitude when the brightness of the adaptation stimulus is at either of the three levels used.

Assuming that the borderline between comfort and discomfort is determined by the size of the pupil response, it is possible to predict the BCD values from the pupil response data by assuming that the borderline between comfort and discomfort occurs when the pupil constriction reaches a certain magnitude. Each of the four graphs in Fig. 10 represents retinal illumination required to produce a pupillary constriction of a given fixed magnitude for various diameters of momentary stimuli and different adaptation levels.

In this study as in the previous study the 1.5-degree, 5.5-degree and 15-degree stimuli have about the same threshold as shown in Fig. 9 but the curves diverge as the brightness of the stimulus increases. It is this characteristic of the data that accounts for the fact that the slopes of the curves in the graphs in Fig. 10 vary from graph to graph. The general level of brightness values increases, also, as the magnitude of the pupillary constriction increases. Included in each of the graphs in Fig. 10 is a dotted curve which represents the Luckiesh-Guth BCD values for an adaptation level of 10 footlamberts (430 trolands). The curve for 450 trolands in the graph for a pupillary constriction of 0.4 mm has about the same slope as the Luckiesh-Guth curve, but

TABLE II.—Retinal illumination in trolands produced by BCD momentary stimuli of different sizes and at different levels of adaptation. The values shown have been computed from data taken from the graph in Fig. 5.

Adaptation Level		Pupil Diameter	BCD Levels (trolands) for different sizes of momentary stimuli		
Footlamberts	Trolands	(in m.m.)	1.5°	5.5°	15°
1	67.25	5.	24,203	10,756	4,033
10	430.	4.	43,050	18,942	7,749
100	2110.	2.8	59,052	25,308	9,912

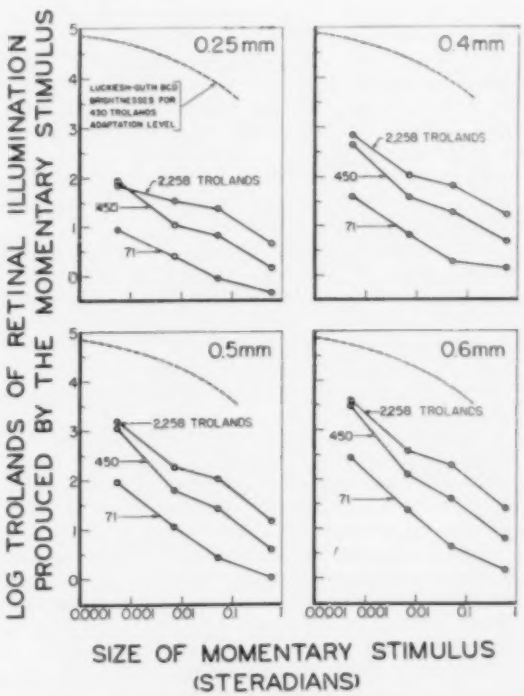

Figure 10. Retinal illumination required by momentary stimuli of different sizes to produce pupillary responses of different magnitudes as indicated in the upper right hand corner of each graph. The different solid line curves in each graph represent different levels of adaptation. The dotted curve in each graph represents the Luckiesh-Guth BCD curve for an adaptation level of 430 trolands.

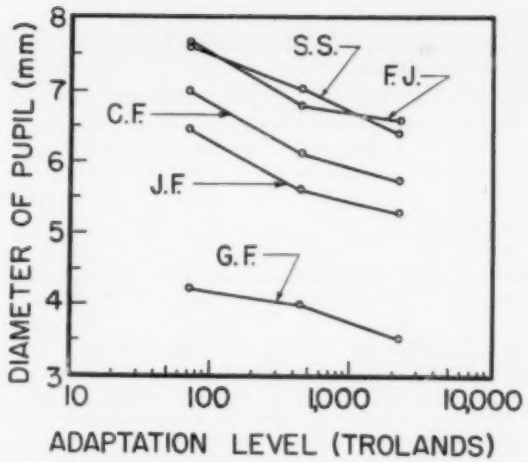

Figure 11. Pupillary diameter of the right eye after exposure of the left eye to the adaptation stimulus for 50 to 90 seconds. The different curves represent different subjects.

the brightness level required for this constriction is much lower than Luckiesh-Guth BCD level. The trend found in the series of graphs indicates that a constriction higher than 0.6 mm would require a brightness level more in line with the Luckiesh-Guth BCD level but the slope of the curve would be too steep.

Note that Luckiesh and Guth used naked eyes, *i.e.*, without artificial pupils; and consequently during a one-second stimulus the pupil will constrict and cut down on the amount of light entering the eye. It is estimated that the total exposure (retinal illumination × time) for a one-second stimulus is about one-half what it would be if the original size of the pupil were maintained throughout the momentary stimulus. If allowance were made for this, the Luckiesh-Guth curves in Fig. 10 would be lowered about one-third of a log unit. After making this allowance the conclusion is that the BCD pupillary constriction is larger than 0.6 mm and that the BCD pupil constriction is a function of size of the stimulus.

Fig. 11 presents data on pupil sizes for the five subjects used in this study, for the three levels of adaptation. Each plotted point represents an average of 20 measurements of pupil diameter which were made following 50 to 90 seconds of adaptation to the adaptation stimulus.

Words and Phrases Used to Describe the Subjective Experiences Associated with Brief Exposures of Light

General — This phase of the study was concerned with the words and phrases which subjects use to describe the subjective experiences accompanying brief exposures of light.

Procedure — A definite technique of presenting the momentary stimuli was followed. The brightness level of the adapting stimulus was kept constant throughout the experiment at 450 trolands. The subject was exposed to the adaptation stimulus 30 seconds (in some instances 60 seconds) before any momentary stimuli were presented. The momentary stimuli were presented in volleys involving one second on, one second off, one second on, one second off, one second on, and then five seconds off before the next volley. Each subject was required to observe a minimum of three such volleys before attempting to describe the subjective experience. There was no upper limit imposed upon the number of volleys permitted in order for the subject to satisfy himself that he could properly identify the experience.

The first judgment a subject was required to make involved momentary stimuli at a low brightness level, after which the brightness level was varied in steps of one log unit. In changing from one brightness level to another, the subject was permitted to move his head out of the instrument (see Fig. 1) and a certain period of time was used by the subject to describe his experience. During this time the overhead lights in the room were turned on. The walls of the room were black and had a brightness level less than one footlambert which was much lower than the adapting stimulus used in the experiment. This interval of time permitted an almost complete recovery from the series of volleys of momentary stimuli just preceding.

At the beginning of the experiment, each subject had an opportunity to make at least one trial run with the 51-degree momentary stimulus, using a series of brightness levels. After the trial run or runs, an additional run was made, and this time the descriptions of the subject were reported. Another such run was made using the 1.5-degree momentary stimulus.

Results — A typical set of data are illustrated in Table III, which gives the results for Subject J. F. using 51-degree and 1.5-degree momentary stimuli. The descriptive terms and phrases used by the other subjects differed only in minor respects. When the subjects were shown the descriptive terms and phrases used by subject J. F. (see Table III), they found that these terms and phrases could be used to identify their own experiences. They were willing to use these terms and phrases in describing their own experiences associated with the various momentary stimuli of different sizes and brightnesses. A study of these words and phrases brings out the fact that there are two or more separate factors involved in the comfort-discomfort aspect of the visual experience; *i.e.*, the term "desire to squint" suggests some type of experience which is based upon a different factor than the experience described as "unpleasantness" or "tenseness." The different objective symptoms such as blinking, squinting and tearing suggest a multi-

TABLE III.—Words and phrases used by subject J. F. to describe his experiences associated with momentary stimuli of different sizes and brightnesses. Adaptation level constant at 450 trolands.

Momentary Illumination in Trolands	Diameter of Momentary Stimulus	
	1½°	51°
10		Very slightly annoying.
100		Annoying, slightly unpleasant.
1,000	No discomfort or annoyance.	Near BCD level; slight desire to squint and orbital tenseness. Prefers not to look at momentary stimulus.
10,000	Annoying, slightly unpleasant.	Definitely uncomfortable, tenseness, desire to squint. May be slight amount of irritability.
100,000	Uncomfortable, some tenseness and desire to squint, prefer not to look at it.	Very uncomfortable, squinting. Strong desire to look away. High irritability and tenseness.
1,000,000	Increased severity of previous symptoms, may be slight amount of irritability.	Intolerable to look at it steadily, tearing, involuntary blinking, plus previous experiences in increased severity.

TABLE IV.—TIB and BCD levels and pupillary responses to momentary stimuli at the BCD level. Adaptation level constant at 450 trolands.

Subject	Size of Stimulus	Condition of Eyes	BCD (Trolands)	Pupillary Constriction (mm)	TIB (Trolands)
J. F.	1.5°	Normal	150,000	1.57	**
		Drug one eye	280,000	1.63	**
		Drug both eyes	*	*	**
G. F.	1.5°	Normal	74,000	.33	**
		Drug one eye	52,000	.33	**
		Drug both eyes	*	*	**
F. J.	1.5°	Normal	145,000	1.66	415,000
		Drug one eye	293,000	1.72	**
		Drug both eyes	187,000	.97	**
N. B.	1.5°	Normal	*	*	**
		Drug one eye	*	*	**
		Drug both eyes	*	*	**

*The brightest stimulus available did not produce discomfort.
**The brightest stimulus available did not produce involuntary blink.
†No records of pupil response were made for this subject.

plicity of factors involved in the situation. They also suggest that reflexly activated motor mechanisms of the orbit play a major role in the discomfort associated with a brief exposure of light.

Determination of the BCD Level

General.—This phase of the study was to determine, precisely, the brightness level which corresponds to the borderline between comfort and discomfort.

Procedure.—From data, such as given in Table III, we selected the filter for the momentary stimulus which would represent a level above BCD when the variac was at a maximum. The brightness was reduced by means of the variac to a level well below the BCD and during a series of volleys (as described in preceding procedure section) the subject was permitted to adjust the voltage with the variac to determine the borderline between comfort and discomfort. Each subject was allowed to select his own criterion as to what constitutes this borderline.

The subjects described their criteria as follows:

J. F.—The BCD level is characterized by a slight tenseness in the orbit (both eyes) and a tendency or desire to squint both eyes. Neither of these experiences is severe but they are definitely noticeable.

N. B.—The BCD level is characterized by a desire to blink.

F. J.—The BCD level is characterized by a fairly high degree of orbital tenseness and some slight squinting, and the eyes feel like they might shed tears. Similar to walking out in the bright sun after just getting up in the morning.

G. F.—The BCD level is the one at which the momentary stimulus becomes annoying and unpleasant and I prefer not to look at it.

Five separate determinations of the BCD level were made for each subject for each of two momentary stimulus sizes. An average for each set of five determinations was computed, and the results given in Table IV.

Results.—We compared our data for a 1.5 degree momentary stimulus with those of Luckiesh and Guth.[3] By interpolation we determined from Fig. 5 that a stimulus having a diameter of 1.5 degrees (.00857 steradians) and a brightness of 1050 ft-L (45,000 trolands*) superimposed upon an adaptation stimulus of 10.5 ft-L (450 trolands*) would be at the borderline between comfort and discomfort. This value of 45,000 trolands for a 1.5 degree stimulus with an adaptation level of 450 trolands for the Luckiesh-Guth average subject is somewhat lower than the values obtained with our subjects. The value for J. F. is 150,000 trolands, that for G.F. is 74,000 trolands and that for N. B. is 455,000 trolands. Subject F. J. obtained no discomfort with the brightest momentary stimulus available (1,000,000 trolands). The difference between our results and those of Luckiesh and Guth are partly due to the criteria used and partly to the fact that the momentary stimuli are applied to both eyes in the Luckiesh-Guth experiment. However, Luckiesh and Guth used naked eyes and, as already noted, the pupil will constrict during a one second stimulus and cut down on the amount of light entering the eyes. If allowance were made for this, the difference between BCD values for our subjects and that for their average subject would be even greater.

Note that the data in Fig. 5 apply to the average subject in the Luckiesh-Guth experiment, and that the BCD values for the various subjects in the experiment varied as much as ½ log unit for a given momentary stimulus size and adaptation brightness.

*These values are based on the assumption that the pupil size in the Luckiesh-Guth experiment is 3.97 mm. This is the value found by Reeves for binocular adaptation to a level of 10.5 footlamberts.

Pupil Responses Produced by Brief Exposures of Light at the BCD Levels

General.—The BCD levels determined in the preceding section and listed in Table IV for the 1.5-degree and 51-degree momentary stimuli, for each of three subjects, were used to obtain the pupil responses to brief exposures of light.

Procedure.—The brightness of the momentary stimulus was adjusted to each of the above levels by means of the varias, and at each level a photographic record was made of the changes in pupil size of the right eye produced by brief exposures of light presented to the left. These momentary stimuli were presented in volleys; each represented by one second on, one second off, one second on, one second off, one second on, followed by five seconds off before the next volley. Responses to three such volleys in sequence were recorded. The first volley was preceded by at least 30 seconds of exposure to the 450 troland adaptation stimulus. The pupil constriction produced by the first momentary stimuli in each of the three volleys, was measured and these three constrictions were averaged to determine the average pupil constriction associated with the BCD brightness.

Results.—The BCD brightnesses and the associated pupil constrictions for stimuli of different sizes are given in Table IV. The pupil constriction which occurs when a momentary stimulus of BCD brightness is presented is of the order of 1½mm but varies slightly from subject to subject. It also varies with the size of the stimulus. The use of a three momentary stimuli volley makes it possible to compare our subjective data with those of Luckiesh and Guth, but it makes it difficult to give a numerical assessment to the pupil response for a three momentary stimuli volley because the responses to the second and third momentary stimuli in a volley are much smaller than the response to the first. This difficulty becomes apparent when attempting to relate the data in this section to those in the first section where the momentary stimuli were spaced ten seconds apart. This section has demonstrated that the BCD pupil response varies with area. This fact is important because it means that pupil constriction *per se* cannot be used as an index of discomfort without making allowance for the distribution of light on the retina. However, this should not be overemphasized because the effect of area is small in comparison with that of brightness and hence pupil constriction *per se* does have limited value as an index.

There are two possible ways to account for the fact that the BCD constriction varies with area. One is that different distributions of light on the retina might produce different distributions of responses amongst the motor units of the sphincter muscle of the iris, (e.g. motor units near the margin of the pupil might be more active than those located further away, and one such distribution may be more effective than another in stimulating fifth nerve endings. The second explanation is that some other factor like general tension in the muscles outside the eye summates with constriction of the pupil to produce discomfort, and the two factors are affected differently by different distributions of light on the retina.

Effect of Homatropine on the BCD Level

General.—In this phase of the study homatropine was used to determine the role of pupil constriction in producing the discomfort associated with a brief exposure to light. Homatropine paralyzes the sphincter muscle of the iris by blocking the myoneural junctions which abolishes the response of the pupil to light.

Procedure.—Two drops of 2 per cent aqueous solution of homatropine were instilled into the left eye every ten minutes until six drops had been instilled. One hour after the last instillation of drops the BCD brightness was determined in the same manner as previously described. Drops were then instilled into the right eye in the same manner, and an hour after the last drops had been instilled into the right eye, an attempt was made to determine the BCD brightness.

Results.—The results of this experiment are presented in Table IV which shows that the paralysis of the left eye has little or no effect on the BCD brightness but as soon as both are paralyzed, it becomes impossible to determine the BCD brightness for either the large momentary stimulus or the small momentary stimulus. This is true except in the case of one subject F. J. whose results will be given special consideration a little later.

One subject, G. F., found no discomfort at all associated with the brightest momentary stimuli available with the apparatus (1,000,000 trolands) immediately following paralysis of both irises; but when he went outside into the open and faced the sky, this produced an irrepressible blinking and squinting and eventually tearing. Accompanying these symptoms there was a definite discomfort which could be avoided by occluding one eye entirely and part of the field of the opposite eye or by wearing neutral filters over the opposite eye. The experiment was carried out on the first of September and, although the brightness of the sky on this particular day was not measured, available data[5] on sky brightness for a clear day indicate that the sky brightness is of the order of 2.5 lamberts. With an 8mm pupil this would produce a retinal illumination of 400,000 trolands. The failure to experience discomfort with the brightest momentary stimuli provided by the equipment is probably dependent upon the limited extent and duration of the exposure.

Nutting[6] found that continuous exposure to a 36cm x 36cm surface viewed at 34cm would produce discomfort if its brightness were raised to 92 lamberts (approximately 368,000 trolands with a pupil 2mm in diameter).

When a neutral filter having a density of three and a diameter of 1½ inches was held close to one eye while the other was kept closed, subject G. F. was able to face the sky in comfort. The use of a two-density filter or holding the three-density filter 2 inches in front of the eye brought back the symptoms, and if the filter were held at a distance of 4 inches from the eye, its effect was negligible.

Normal pupils may constrict to a size of approximately 2mm in the open and assuming a value of 8mm for a pupil dilated with homatropine, it may be deduced that allowing the light reflex to operate reduces the area of the pupil by a factor of 1.61 or 1.2 log units.

Subjects J. F. and N. B. were able to detect a mild form of discomfort with paralysis of both irises when maximum size and brightness were used for the momentary stimuli, but it was qualitatively different from the type of experience which had been previously used in identifying the borderline between comfort and discomfort. These same subjects reported severe discomfort when going outside.

Subject F. J. reported no change in his subjective experiences produced by homatropine, following complete paralysis of both irises. In this particular case the BCD level was very high in comparison with the levels for other subjects. It is probable that the type of discomfort following

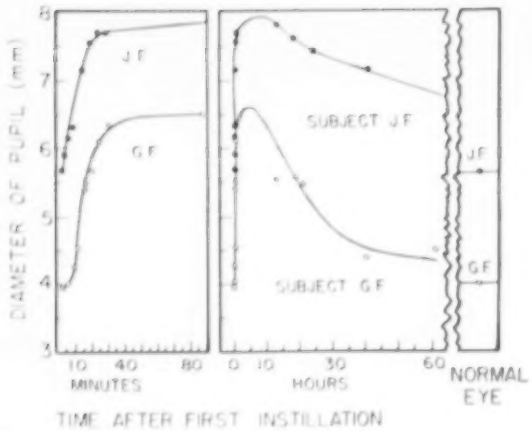

Figure 12. Rate of onset and recovery from homatropine paralysis. In each case two drops of a 2 per cent aqueous solution was instilled into the right eye every ten minutes until six drops had been instilled. Each point represents the diameter of the right pupil after exposure of the left eye to a 450 troland adaptation stimulus for at least ten seconds, and also represents an average of two measurements. The data for the normal eye are taken from Fig. 11.

bilateral homatropinization which was experienced by subjects J. F. and N. B. was used by F. J. as a criterion for the borderline between discomfort and comfort. If this is the case, it means that constriction of the pupil was contributing little or nothing to the experience of this subject. Subject F. J. also experienced extreme discomfort in bright sunlight.

The sort of discomfort which the subjects experienced with homatropinized eyes out of doors differs from the experience of discomfort which is experienced just above the borderline between comfort and discomfort in having an experience of tenseness and desire to squint as the predominating factor. This qualitative observation points to the conclusion that it is necessary to consider two factors: one, the constriction of the pupil, and the other the activity of the muscles associated with the act of blinking and wrinkling of the brows and skin of the forehead. There is also the factor of the general increase in tension of the extraocular muscles.

The data for three of the subjects shows that the threshold for discomfort associated with the other muscles of the orbits is higher than that for the sphincter of the iris, and this is of some value in establishing the fluctuation of the pupil as a useful index of the borderline between comfort and discomfort.

Analysis of Recovery from Homatropine Paralysis to Trace the BCD Back toward Normal

This phase of the study was to trace the BCD back toward normal during recovery from homatropine paralysis of the irises of both eyes. Fig. 12 shows the rate of onset and recovery from homatropine paralysis. These data represent measurements of the absolute size of the pupil of the right eye when the left eye is exposed to the 51-degree adaptation stimulus of 450 trolands. Each point is an average of two measurements made during the period from 10 to 50 seconds after the onset of the adaptation stimulus.

In the case of subject G. F. a complete paralysis was not attained because at 87 minutes after the first instillation of homatropine to the right eye, when the paralysis was maximal, a 51-degree momentary stimulus of the highest brightness produced a $\frac{1}{4}$ mm constriction. In the case of J. F. and F. J. the paralysis was complete. In the case of subjects G. F. and J. F. there was quite a lapse of time before it was possible to measure the BCD brightness with a 51-degree stimulus or a 15-degree stimulus. Following this we traced the return of the BCD brightness toward the normal, but in each case the experiment was terminated before the BCD had time to return completely to normal.

The size of the pupil response was measured at the BCD level, except in one instance (Fig. 13, 40 hours after the first instillation of homatropine in the right eye) when the record obtained could not be analyzed.

In the case of three subjects the momentary stimulus of highest brightness failed to reach the BCD level at the time the paralysis of the right sphincter reached its maximum. This is true for the 51-degree stimulus as well as the 15-degree stimulus. Since the highest brightness available is 2 log units or more above the BCD level for normal eyes, this may be taken as evidence that pupil constriction in these subjects is an actual source of discomfort.

Note in the case of subject G. F. that the BCD pupil response decreases as the paralysis wears off, but increases in the case of subject J. F. This is probably due to the difference in initial pupil sizes for the two subjects. The probable reason why the pupil response of G. F. is so small when the eyes are normal is that the initial pupil diameter is small and probably approximates the mechanical limit of constriction. Thus, when the sphincter is partially paralyzed the same change in tension will result in a greater change in pupillary diameter. Subject J. F.'s change in the BCD pupil response during the recovery from paralysis shows that less constriction is required to produce discomfort in a partially paralyzed pupil than a normal pupil. Since partial paralysis involves a blockage at some of the myoneural junctions, the contraction would probably involve an irregular pattern of motor units. The non-uniform pull in different parts of the muscle which results from this might increase the effectiveness with which a pupil con-

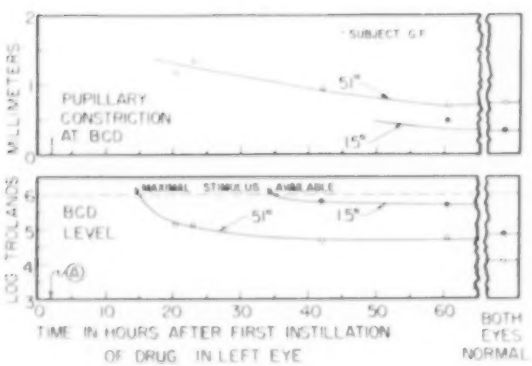

Figure 13. BCD levels for subject G. F. for momentary stimuli 1.5° and 51° in diameter and pupillary responses to momentary stimuli at the BCD level during recovery from homatropine. The adaptation level constant at 450 trolands. Point A represents the first instillation of homatropine in the right eye. The data for the normal eye are taken from Table IV.

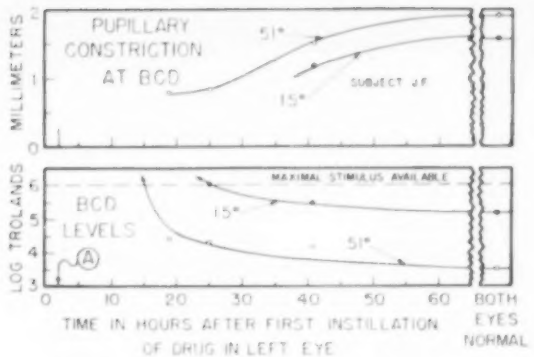

Figure 14. BCD levels for subject J. F. for momentary stimuli 1.5° and 51° in diameter and pupillary responses to momentary stimuli at the BCD level during recovery from homatropine. The adaptation level constant at 450 trolands. Point A represents the first instillation of homatropine in the right eye. The data for the normal eye are taken from Table IV.

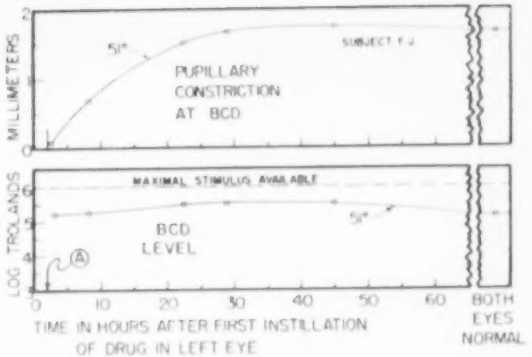

Figure 15. BCD level for subject F. J. for a 51° momentary stimulus and pupillary response to 51° momentary stimuli at the BCD level during recovery from homatropine. The adaptation level constant at 450 trolands. Point A represents the first instillation of homatropine in the right eye. The data for the normal eye are taken from Table IV.

striction would stimulate fifth nerve endings. This factor would operate in subject G. F., also, but would be more than compensated by the effect of smallness of the normal pupil.

Effect of Homatropine on the TIB

General — An involuntary blink may be evoked by several types of sensory stimulation including a brief exposure of light or touching the eyelashes or the cornea. It is not unreasonable to suppose that stimulation of the fifth nerve endings in the iris might also produce involuntary blinks.

A blink which occurs in direct response to a brief exposure of light when no voluntary effort is made to suppress it, will have a latent period of less than 0.1 second and cannot be affected by a feedback from the fifth nerve endings in the iris. But, if a voluntary effort is made to suppress the blink, the excitation from the retina would be pooled with the feedback from the sphincter of the iris to build up an irrepressible desire to blink and the ensuing blink or blinks might have a reaction time of a second or more. In such a case it is conceivable that homatropine might affect the TIB. However, if the effort to suppress is ineffective or if the subject merely reports when unsuppressed involuntary blinks first occur, then the measured TIB will not be affected by homatropine.

Procedure — The threshold values for involuntary blinking (TIB) are shown in Table IV. These values were determined by varying the variae in the same manner as in the case of the BCD measurements (see section on determination of the BCD level) and finding the level at which the subject could no longer suppress involuntary blinks.

The only instruction given the subjects was to report when they could no longer prevent blinking. That successful efforts at suppression were being made was determined on the basis of the reaction times of the blinks which are recorded on the same record as the pupil responses. (See Fig. 4.)

Results — The blink reaction time of each subject varied from momentary stimuli to momentary stimuli and appeared with some momentary stimuli but not with others. The reaction times were seldom shorter than 0.5 second and practically never shorter than 0.3 second. In previous studies[2,4] blinks with a reaction time of 0.1 second or less

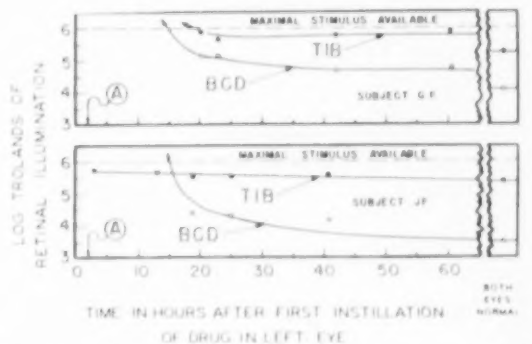

Figure 16. BCD and TIB levels for subjects J. F. and G. F. during recovery from homatropine paralysis. The adaptation level constant at 450 trolands.

were repeatedly found. These values are in accordance with the values commonly accepted for the reaction time of the direct blink reflex to light. We concluded that the subjects in the present study were making successful efforts at suppression of involuntary blinks.

The TIB of each subject is raised by using homatropine. Note that in one case (F. J.) even though the BCD level is not affected by homatropine, the TIB is. This indicates that the irises of F. J. have little or no pain sensitivity but can still contribute to the blink reflex. In the cases of subjects G. F. and J. F. we traced the TIB during the recovery from paralysis. This was successful only with the .1 degree momentary stimulus since in the case of the 1.7 degree stimulus the highest level of brightness failed to evoke an irrepressible desire to blink.

The results are shown in Fig. 16 which also shows the relation of TIB to the BCD during the recovery from paralysis.

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DISCUSSION

DAVID A. TOUSEY:* The methods of measurements that the authors have described offer a prospect of making objective measurements of visual discomfort, which has generally been regarded as a subjective effect that we recognize but cannot measure. We are indebted to the authors for a clear presentation of a difficult subject. Here are some questions that may merit further discussion.

What is the relation between visual discomfort and the quantity that we call "fatigue"? As we commonly describe "fatigue," is it simply a measure of accumulated discomfort? For example, a motorist travels on a lighted expressway in which his eyes are subjected to repeated flashes of high brightness from successive street lighting units. Do the measurements here show us how to predict the amount of fatigue, due to lighting, that our motorist will feel at the end of his trip?

One of the especially interesting points in this paper was the wide spread of sensations among the four observers in the tests. Because of this variety of described sensations, such measurements may not be significant except with an average of many subjects. Are four subjects, as used here, enough to obtain such an average? Finally, will such an "average result" be representative enough of *individual* observers to be really meaningful — for example, in describing the discomfort glare effect of street lighting luminaires upon motorists' eyes — or should we not attach more importance to the observers who are most glare-sensitive?

SYLVESTER K. GUTH:** The ultimate aim of lighting research is to provide us with two answers: what and why. We have comprehensive data regarding *what* happens in various visual situations and *what* should be done to make a given situation comfortable. On the other hand, we know only too little about *why* these things happen. This excellent paper is another step forward in giving us a better understanding of the fundamental physiological causes of visual discomfort. We need many more studies of this sort.

The subjective reports of their observers are interesting. Of course, the group was fairly well qualified to describe their experiences when exposed to various stimuli. Naive observers generally do not have the background or vocabulary to do this. Nevertheless, some of the subjective reports volunteered by those who participated in our BCD experiments were very similar to those of the Fugate-Fry observers.

The authors point out certain differences between their results and those obtained in the BCD studies. For example, they found the brightness for a given pupillary constriction to be considerably below the average BCD brightness. Such differences could be caused by any one or a combination of several factors: artificial or natural pupils, actual size of adaptation field, etc. In other words, differences in experimental situations can produce different results. However, such differences should not detract from the value of either investigation. Furthermore, it is entirely possible that the brightness required for the BCD sensation will produce a relatively large pupillary constriction, indicated by the authors to be of the order of 1.5 mm.

It is interesting to speculate on the possibility of using pupillary changes as a basis for developing a so-called "comfort scale." According to our definition BCD means borderline between comfort and discomfort. This is not to be construed as a desirable condition. We would like to have no noticeable discomfort. Petherbridge and Hopkinson found that a source brightness for "just imperceptible glare" was about 20 per cent of the brightness for "just uncomfortable glare." Perhaps various degrees of sensation to glare may be correlated with pupillary constriction.

The difference in BCD brightness obtained by the observers is considered quite normal. This has been found by others who have studied this problem. The generally higher brightnesses selected by these observers may be due to the specific experimental situation.

I hope that Drs. Fugate and Fry will be able to continue this type of investigation. There are many aspects of the problem which still need to be studied. It would be particularly interesting to see if they will be able to obtain information on the additivity of sources of brightness and, if possible, to modify the optical system of their apparatus so that they will not be limited to a small artificial pupil.

EDYTHE POLSTER:† I would like to ask four questions of the authors:

(1) How many observers took part in the studies?

(2) How many cases were studied and how were they selected?

(3) What age groups were covered in the experiment?

(4) Was the general physiological condition of the cases checked or just the conditions of their eyes?

HENRY L. LOGAN:†* This paper does seem to me to raise the question, "Which comes first, the chicken or the egg?" The authors mentioned that in different words in saying "Does the discomfort cause the symptoms, or the symptoms the discomfort?" We may be faced here with a circular phenomenon in which both things operate as causes; that is, muscular tension in the individual may be a primary cause, as well as outside phenomena.

There may be a way to check this. If people could be used as subjects who have been trained in visual relaxation through their occupations, such as actors and actresses, and if in their case the outside phenomena produce results of the same magnitude as in the case of people who normally tense when they face uncomfortable environmental stimuli, we would then know that the outside conditions were the sole cause. However, in experiments with sound reported by Dr. E. Jacobson, persons who were clinically relaxed registered responses as measured by micro-electric techniques of about 10 per cent of the magnitude of unrelaxed persons. Putting it another way, about 90 per cent of the discomfort of unrelaxed persons arose out of their lack of adjustment to the environment and only 10 per cent arose from the outside stimulus.

I suspect something of this sort is also operating in con-

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nection with the visual sense, not only because of the many similarities between the audio and visual systems of the human organism, but also because of the many researches reported by the C.I.E., Secretariat Report 1.4.2, Glare and Adaptation, on which is based the conclusion that "there occurs as well a nervous component of remarkable importance, which determines many features of the eyes' behavior." This nervous component could very well be what is popularly called "nervous tension," but which, more accurately expressed, is muscular tension. Microelectric techniques are necessary to track down this elusive but important factor.

My other comment is to offer my thanks to the authors for this fine contribution. It is a step in the direction toward exploring an unknown area; adding a little more to the map we have to work out before we can get to the point where we can replace unknowns with certainties, or at least good approximations.

LEONARD V. JAMES:* Members of the Society, particularly members of some of the technical committees, have a great need for fundamental data on the reactions of human beings to their visual environments. Some of this information is gradually being made available from the laboratories of our Sustaining Members. It is well to have this checked and expanded through independent researches and from various viewpoints and the existence of the Illuminating Engineering Research Institute makes this possible.

It is through researches such as are being reported in this and similar papers that important thresholds are being indicated. As this information accumulates, it will have practical value in guiding designers of lighting equipment and of lighting installations through providing criteria for appraisal.

It might seem to some that locating the area of discomfort in the eyes is of little practical value. Such an understanding, however, is basic in the analysis of that discomfort and therefore of the causes of such discomfort. As in mathematics, until one understands the symbols and the basic formulae, he cannot hope to solve the advanced problems intelligently.

The Society is to be congratulated upon the establishment some years back of the Research Institute, making possible these fundamental studies, which lead to such important practical results. It is to be hoped that support of the Institute, by members and by Sustaining Members who ultimately will benefit in a large way, will continue and grow. Anything less would be most unfortunate.

J. M. FUGATE and G. A. FRY:† In reply to Mr. Toenjes it may be pointed out that the work was not designed as a study of fatigue which involves accumulated effects over a period of time. It is hoped that our study of the effects of flashes of light may provide some help in the study of the accumulative effects such as occur on a lighted expressway. In accumulating objective data it was aimed to achieve sufficient accuracy to determine whether the pupil responses obey the same laws as visual discomfort with respect to size and brightness of flashing stimuli. These data cannot be applied to lighting problems until we know how to predict discomfort from changes in pupil size. From this point of view our study must be regarded as exploratory and aimed at an understanding of the basic factors.

As Dr. Guth pointed out it is essential to undertake a study of additivity of sources of brightness. This is one phase of the problem which we intend to pursue further. Up to now we have concerned ourselves with the allowance that has to be made for stray light in the eye in the interpretation of the results obtained with multiple stimuli.

The artificial pupil used in our experiment serves a very useful purpose, to keep the retinal illuminance constant while the pupil is fluctuating in size. We believe that if the basic data are formulated in terms of an artificial pupil, results obtained from a natural pupil can be predicted. It will be necessary, however, to make a check test to show whether this is true.

The questions raised by Miss Polster may be answered as follows. The senior author (Dr. Fugate) served as experimenter in all the experiments. Five subjects participated in the objective part of the study and four in the subjective part. Three of these subjects, including the authors, participated in both parts. There was no selection; we used people who were available at the time of the experiment. Ages ranged from 17 to 47. There was no check of the general physiological condition of the cases. To the best of our knowledge everyone was in good health at the time of the experiment.

Mr. Logan's suggestion is excellent and certainly merits investigation. We can only add that another possible approach would be to anesthetize (with drugs) the museum before installed and then repeat the experiment.

*Illuminating Engineering Consultant, La Grange, Ill.

†Stations.

I.E.S. Golden Anniversary Conference

September 17-21 — Statler Hotel — Boston, Massachusetts

The Demand for Professionally Trained Illuminating Engineers

THREE THOUSAND technically trained people qualified in illuminating engineering will be needed to meet the estimated requirements of the lighting field over the next five years. This number is indicated by a recently completed survey by the Committee on Lighting Education of the Illuminating Engineering Society. Many agencies involved in the production or application of light and related radiation have a pressing need for staffs with a background of professional training in the science and the art.

A questionnaire sent to six categories of employers brought replies from 545 organizations presently employing 2257 technically trained people in lighting activities, and reporting a need for 1230 more during the next five years. The sampling was somewhat more comprehensive for the A and B categories than for the others shown in Table I, but the projections from the returns have in each case been made carefully and conservatively.

The figures reflect the highly dynamic character of the lighting industry. In the United States it consumes as much electrical energy as was used for all purposes as recently as 1939. It is unique in the wide scope of its services to human activities and welfare. In this Golden Anniversary year of the Illuminating Engineering Society, developments in light sources and in accessory equipment of diverse optical and electrical characteristics continue at a rapid pace. There is marked progress in knowledge of visual performance and the several factors that determine the effectiveness and acceptability of a lighting system, its suitability to the task and to the environment.

The survey reveals not only the numbers of technically trained people needed but also the areas in which it is desired they be able to function. In most cases the responding employers want an individual qualified to function in several of the listed types of activity. The following percentage figures indicate how the individuals would be employed, and since some would perform more than one function, the figures total 351 instead of 100.

	Per Cent
Research	37
Development of sources or materials	32
Design of lighting equipment	53
Design of operating accessories	16
Design and specification of lighting systems	86
Manufacturing	26
Installation and maintenance	16
Sales engineering	63
Sales	28

For categories C to F of Table I it was reported that the illuminating engineering function would in most cases be in addition to other responsibilities of an electrical, architectural or industrial engineering nature.

Further light is thrown on the needs of the field by the specific training and abilities desired. Almost all respondents listed lighting applications, circuits and controls, the technology of lighting design. Most included principles of architecture and design, color technology, psycho-physical aspects of seeing, physics of light production, and photometry. A large percentage emphasized training or facility in public speaking, reports and correspondence, and elements of salesmanship.

In only a very few of our universities and technical schools is provision made for comprehensive courses and laboratory facilities in illuminating engineering. The survey emphasizes the importance of further consideration by the administrators of such institutions of the opportunities afforded by this field and the needed academic programs. Further details of the survey may be obtained by writing to the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

TABLE I.

	Employing Group	Approximate Number Needed Over Next Five Years
A	Light Source, Lighting Equipment and Accessory Manufacturing including Daylighting and Basic Materials	900
B	Electric Utilities	600
C	Architects and Consulting Engineers	600
D	Electrical Contractors	300
E	Electrical Wholesalers	300
F	Consumer Organizations, Government Agencies and Non-Industry Laboratories	300
	TOTAL	3000

Approved by the Council of the Illuminating Engineering Society, April 1950.

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INSTALLATION ON BURNS FREEWAY, SEVENTH ST. AND U. S. HIGHWAY NO. 101
ARCATA, CALIF. (under fog and moist pavement conditions).

Lighting Freeway Intersections

LIGHTING OBJECTIVE: To provide illumination at highway intersections that will be adequate for safety under fog and wet pavement conditions.

GENERAL INFORMATION: Burns Freeway is located in a section of the middle and northern parts of Humbolt County, a coastal section of Northern California. It is part of U. S. Highway No. 101 which runs from the Mexican to the Canadian borders. This coastal section of Northern California has a high annual rate of precipitation (from three to over six feet) with 120 rainy days each year.

INSTALLATION: Nu-Art Lighting and Manufacturing Company No. NE-962 luminaires having an I.E.S. Type V distribution are suspended from 25-foot bracket arms on 30-foot Union Metal Taper-Tube steel poles and located on spacings which vary from 80 feet to 120 feet. These luminaires were specially designed to provide a broad band of light across the roadway and provide illumination for silhouetting against wet pavement. Each luminaire is equipped with methacrylate resin-treated Alzak aluminum reflectors (in 4-foot lengths for easy maintenance and replacement) and two 96-inch T-12 5800-lumen 600 ma daylight fluorescent lamps. The housing is made of laminated molded fiberglass to resist the corrosive effect of the salt atmosphere. The ballasts are remotely located in weather-proof boxes mounted on the poles. Horizontal roadway illumination (measured ninety days after installation) at main intersections varied from 0.75 to 1.0 foot-candle and at secondary intersections averaged 0.5 footcandle. One footcandle is maintained at the head of each dividing strip at both main and secondary intersections.

(next)

A.I.A. File No. 31-

Figure 2. Daylight view of secondary intersection.

Figure 3. Night-time view of secondary intersection.

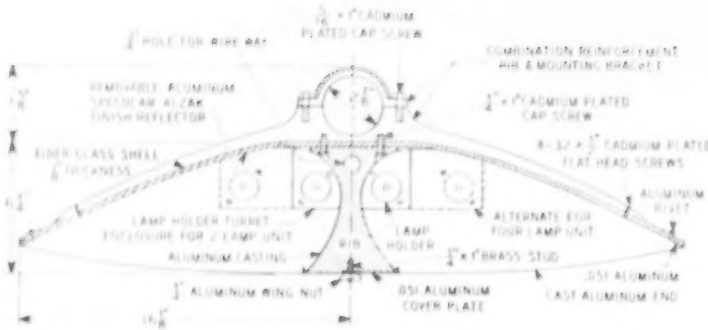

Figure 4. End view of luminaire.

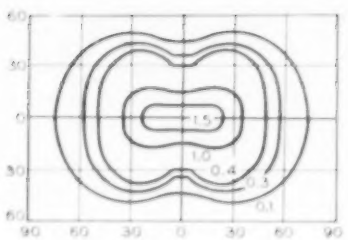

Figure 5. Isolux curve (footcandles) representing measurements by State of California electrical engineers 9 days after installation. Luminaires at 30-foot mounting height.

More recent installations on the same freeway have used the same luminaires equipped with two 96 inch T 12 7250 lumen 800 ma cold temperature rapid start fluorescent lamps.

Field observation during wet pavement conditions shows that the pavement brightness pattern and visibility exceed those with conventional sources with less glare.

Lighting designed by Roy W. Matthews, Traffic Engineer, California State Division of Highways, Sacramento, Calif. and installed by Leonardi Electric Co., San Rafael, Calif.

Lighting data submitted by John C. Epperson, J. C. Epperson Co., 50 Hawthorne St., San Francisco, Calif., as an illustration of good lighting practice and to aid in the design of similar installations.

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Series XXI 7-56

Lighting for Commercial Kitchens

Prepared by the Subcommittee on Kitchen Lighting of the Committee on Institutional Lighting of the Illuminating Engineering Society

Preface

The subcommittee that made this study was appointed from among practicing members of the Illuminating Engineering Society assisted by an advisory group of executives interested in mass feeding suggested by the National Restaurant Association. The advisory group was formally appointed by the President and Council of the Illuminating Engineering Society; particular recognition is due these people for their willingness and aid in bringing the project to successful conclusion. The work was facilitated through the selection of all persons in both groups from the Chicago area, where they could readily get together for research and discussions.

Special acknowledgment is due Colonel Paul P. Logan, Director of Research of the National Restaurant Association, for encouragement and advice; the executives of the John P. Harding Restaurants for assistance and access to their kitchens for study; and Charles L. Staples, Managing Editor of *Institutions Magazine*, for encouragement and assistance in getting organized.

The characteristics of all kitchen tasks were studied first by subcommittee members and then by the entire committee. In some cases, such as determining the best color of the light, the advisory group was included in the study.

1. Introduction

1.1—*Commercial Kitchen Operation*—While most commercial kitchens are not departmentalized as to space, the overall operation can be separated into seven specific parts or functions as follows:

(a) Receiving and storage areas
(b) Vegetable inspection and preparation
(c) Quantity cooking
(d) Quantity baking
(e) Short orders
(f) Service, checking and pricing
(g) Washing dishes, pots and pans
(h) General area

1.2—*Seeing Tasks* — Lighting makes seeing possible and speeds the activity which is dependent upon that seeing.

1.2.1—*General Analysis of Seeing Tasks*— Seeing of any detail is influenced by the *size* of that detail, by its *contrast* with its background, by the *time* available or alloted to the seeing effort, and by the general brightness of the task which causes the impression of the visual pattern registered on the retina of the eye. (The last named may be compared to the audible volume in radio reception.) Seeing is also influenced adversely by great variations in brightness; (1) directly, if these appear in the immediate task, such as reflections of bright sources in polished surfaces of utensils, and (2) indirectly, if marked variations are away from the task but dominant in the general field of view. In the latter case they may cause strain, nervous tension or fatigue. Other conditions affecting seeing are the color of the

Approved by the Council of the Illuminating Engineering Society, February 1956.

Subcommittee on Kitchen Lighting

Carl W. Zerson, *Chairman*, Managing Director, Chicago Lighting Institute
George Gilleard, Assistant Chief Engineer, Curtis Lighting, Inc.
Leonard V. James, Illuminating Engineering Consultant
A. P. Larson, Test Engineer, Commonwealth Edison Co.
Charles T. Masterson, Architectural Consultant, General Electric Co.
William D. Richards, Lighting Engineer, Chicago Lighting Institute
Edwin L. Riego, Lighting Engineer, Marshall Field & Co.
Maurice W. Ross, Lighting Engineer, Commonwealth Edison Co.
Lawrence A. Witt, Lighting Engineer, Public Service Co. of Northern Illinois
Edward J. Wolff, Consulting Engineer

National Restaurant Association Advisory Group

Harvey J. Finison, Armour Research Foundation, Technology Center
Beatrice Hughes, Vice-President, Harding Restaurants (succeeding James P. Harding, President, deceased)
Colonel Paul P. Logan, Director of Research, National Restaurant Association
Leo Lyons, Director, St. Luke's Hospital
Florence Pope, Retired Director of Residence Halls and Commons, University of Chicago
Robert F. Quain, General Manager, Conrad Hilton Hotel
Charles L. Staples, Managing Editor, *Institutions* Magazine
Robert W. Steenbert, Manager, Restaurant Division, Marshall Field & Co.
Frank O. Washam, Director of Food Service, Chicago Board of Education

Committee on Institutional Lighting

James H. McCulloch, *Chairman*

Joel Rubin — William H. Smith — R. M. Smart
George Smedberg — C. I. Sayles — Carl W. Zerson

Steam chefs, steam kettles and walk-in refrigerators.

task details, and the color contrast of these details determined in part by the lighting.

1.2.2—*Specific Analysis of Seeing Tasks.*

1.2.2.1—*Receiving and Storage Areas* The person doing the receiving must check the purchase order copy against items listed on the delivery ticket; usually both are handwritten and often carbon copies. Visual inspection consists of counting the number of crates or cartons and examining for shipping damage. The purchase order and delivery ticket are the critical visual tasks which are performed on the move.

1.2.2.2—*Vegetable Inspection and Preparation* **(a)** This work includes removing wilted and spoiled vegetables from the good; here the color of the light source is important. Preparation involves peeling, slicing, dicing and cutting both by machine and by hand; these are hazardous operations and require good lighting.

(b) The sense of touch also aids in inspection. For example, lettuce and carrots which are soft and limp should not be used for salads. Limp lettuce may still retain its color and show no visual signs of rust. The sense of touch is equally important in inspecting other foods.

1.2.2.3—*Quantity Cooking* — Seeing tasks in this area include inspecting food during cooking, moving the raw and finished goods, and maintaining a clean working space. The detail may be small and of poor contrast. Large exhaust hoods may cast shadows which can be minimized with special underhood lighting.

1.2.2.4—*Quantity Baking* — Seeing tasks here are similar to those for quantity cooking (see section 1.2.2.3), plus those involved in mixing and weighing raw materials. Ovens often are equipped with windows and interior lighting to facilitate seeing. For large scale baking operations see "Lighting for Bakeries," ILLUMINATING ENGINEERING, August 1950.

1.2.2.5—*Short Orders* — Seeing tasks here are similar to those for quantity cooking (see Section 1.2.2.3), plus those involved in rapid operation and the need for frequent cleaning.

1.2.2.6—*Service, Checking and Pricing* — One of the most critical seeing tasks in the entire kitchen is at the checker's stand. The requirements include checking (a) items on tray, (b) tray and bill against menu, and (c) prices on check and menu; adding up total and tabulating type of meal for inventory count.

1.2.2.7—*Washing Dishes, Pots and Pans*— Dish washing involves preparation of dishes for the washer, the washing itself and final inspection and disposal of the dishes. Where automatic washers are used, interior lighting frequently is provided. Checking for remaining soil (often of small hard to distinguish spots or areas) is the most important seeing task.

1.2.2.8—*General Area* — The maintenance of sanitary conditions in the kitchen is extremely necessary and important. Illumination of the general area shall render all dirt visible, including that in corners and other out of the way places.

Chef's section; ranges, fryers, ovens, chef's table and overhead pot rack.

Salad preparation section, chefs' area and hot food pass-through thermotainers in the background.

Bake shop

Dish washing room with soiled dish return conveyors in background and clean dish tables in the foreground.

2. Summary of Lighting Recommendations

2.1—*General* — The following recommendations involve the use of currently available light sources and equipment, and represent a reasonable expenditure at current costs and electric rates for the benefits derived.

2.2—*Recommended Illumination Levels* — For inspection, checking and pricing, where a rapid and accurate seeing requirement may be combined with the mental distraction of computing the total price of the serving, a minimum of 50 footcandles maintained in service is recommended. In all parts of the kitchen, except sections devoted to inspection, checking and pricing, a minimum of 30 footcandles maintained in service is recommended.

2.3—*Color of Light Source*—(a) The use of incandescent filament or one of the color-improved* white fluorescent lamps is recommended (see Appendix). Incandescent filament lamps are available in various types and have the advantage of simplicity and flexibility, and require less expensive luminaire installation. Fluorescent lamps are more efficient (more light can be obtained per watt consumed and from a given wiring system), and have a lower rate of heat radiation.

(b) Color preference is partly influenced by the experience and opinions of the users. If fluorescent lighting is used, the color of the light can be changed at will simply by changing the lamps until the desired color effect is found.

2.4—*Control of Glare*—(a) *Direct glare* at the source may be prevented by effective screening in the luminaire. Since any high brightness within 30 degrees above the line of sight is objectionable, this screening should normally extend to a point at least 30 degrees below horizontal. Possible exception to this is in the lengthwise viewing of fluorescent lamps (lengthwise of their axes where louvers may be unsatisfactory on a sanitation basis). Where the shielding extends to 45 degrees below horizontal, it reaches the point at which the brows normally protect the eyes.

*Phosphors or luminous powders used in color-improved fluorescent lamps: either improved warm white or improved cool white, contain additional red in their radiation.

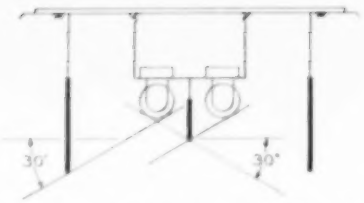


Figure 1. Luminaires should provide a minimum of 30-degree shielding.

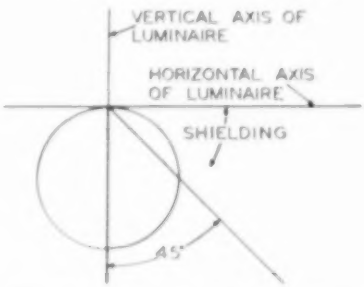


Figure 2. Lighting equipment should provide wide distribution of light to illuminate vertical surfaces and uniform illumination of horizontal surfaces. This curve represents a level of light at various angles from horizontal to vertical.

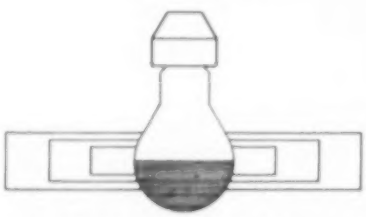


Figure 3. This silvered-bowl lamp and concentric ring louver unit has no horizontal reflecting surfaces to collect dust. The light source is shielded for all viewing angles.

(b) *Reflected glare* results when surfaces within the line of vision are polished; bright images then may be seen in the surfaces. Such spots can be exceedingly objectionable, resulting in discomfort and fatigue. Incandescent filament lamps are bright and, where reflected glare is a possibility, should be concealed above an opaque or diffusing material in the luminaire. Silver coating the bowl of the lamp (so-called silvered-bowl lamp) also accomplishes this purpose. Fluorescent lamps, delivering their light output from a large area of powder-coated glass which has a relatively low brightness, can be used without this concealment from below, for normal kitchen use.

2.5—*Brightness Ratios* — **(a)** Current good lighting practice has established that best results are obtained when the brightness variation of adjacent areas, particularly within the working field, does not exceed 3 to 1, the work itself being the brighter when there is a difference. A maximum limit of 10 to 1 is recommended for non-adjacent areas.

(b) It is assumed that the entire kitchen will be lighted when any part of it is in use. If this is not to be the case, at least part of the general lighting not being directly used should be turned on so as to avoid poor visual and psychological effects of darkened areas.

2.6—*Recommended Reflectances* — To obtain desirable brightness balance the following reflectances are recommended for surfaces in commercial kitchens:

ceiling	80%
walls	60%
equipment, preferably	25 to 30%
floors, not less than	15%

2.7—*Recommended General Types of Luminaires and Their Application*—(a) Luminaires should provide a minimum of 30-degree shielding of the lamps as shown in Fig. 1. For a possible exception, see Section 2.4 (a).

(b) The light distribution should be such that high candlepower is provided at a wide angle (45 degrees) to illuminate the vertical surfaces and to provide uniform illumination of the horizontal surfaces (see Fig. 2).

(c) Luminaires should be designed for ease in cleaning and relamping, and for high reflectance permanent type surfaces; examples are porcelain; enamel; white, mirrored and prismatic glass; and Alzak aluminum. All reflecting surfaces shall approach the vertical as nearly as possible so that dust will not adhere readily. (See Figs. 1 and 3.)

(d) The luminaire design should provide for self-cleaning by having an opening above the lamps (see Fig. 5) to create air circulation or chimney effect, carrying the dust, etc. out of the luminaire. Light from the top of the lamp is utilized with this design to illuminate the ceiling and to reduce the brightness ratio between the luminaire and the adjacent ceiling area. Light on the ceiling reduces the tunnel effect found with totally direct

type lighting luminaires, and also reveals if there are cobwebs on the ceiling or dirt in the corners of the kitchen.

(e) The installation of any type luminaire should take into consideration shielding the lamps from those entering and leaving the kitchen area. This is of particular importance when the adjacent dining area is illuminated to lower levels of illumination. Even the relatively low brightness of unshielded fluorescent lamps will require the eyes to adapt themselves at first. This period of adaptation time is one of partially impaired vision. (An extreme analogy to this is to walk from a movie theatre into the sunlight.) The luminaires should be oriented so that most workers view them in the shielded direction. When this is not the case, a type of luminaire should be selected that provides shielding of the lamp in all directions, (see Figs. 3 and 5).

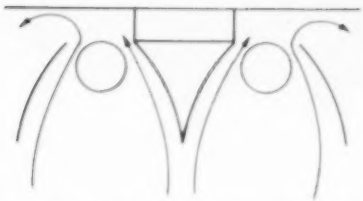


Figure 4. Luminaires open at the top provide a chimney effect which carries dust up away from the lamps and reflecting surfaces.

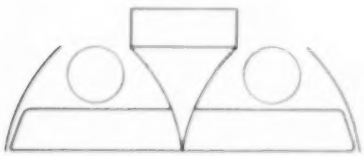


Figure 5. Fluorescent luminaire with shielding sides and cross louvers.

Figure 6. Incandescent luminaire with sealed glass enclosure around lamp.

Figure 7. Shatterproof and vaporproof fluorescent luminaire.

Figure 8. Seven test booths.

(f) In larger kitchens having quantity cooking and baking, moisture and flour dust conditions may also exist; vapor-tight or dust-proof luminaires are recommended in these locations. (See Figs. 6 and 7.)

(g) Local lighting should be necessary only for locations such as baking ovens, refrigerated cases, dish washers, and other places which cannot be served adequately by the general illumination. This type of local lighting is usually an integral part of the kitchen equipment.

Appendix — Procedure to Determine the Recommended Levels of Illumination and Color of Light Source

(a) *Levels of Illumination.* — Extensive tests were made with the Luckiesh-Moss Visibility Meter, both in restaurant kitchens and on food samples brought to the laboratory. These tests indicated a uniform general lighting system providing 30 footcandles to be desirable. In all cases a careful comparison was made with similar commercial and industrial seeing tasks for which desirable levels have previously been established. Because of the manner in which the various operational functions are usually mingled in the kitchen space, this common solution of 30 footcandles was felt to be the desirable one. The exception to this value is in the inspection, checking and pricing section where a minimum of 50 footcandles maintained is preferred (see Section 2.2).

(b) *Color of Light Source.* — Seven booths (see Fig. 8), identical in size and in the color of interior surfaces, were lighted to approximately the same level of illumination by means of different light sources. One was incandescent filament, and the others fluorescent as follows: daylight, cool white, warm white, color-improved cool white, color-improved warm white, soft white. These lamps differ only in degree of whiteness, tending toward either the cool or warm end of the spectrum. Virtually all members of the committee and of the advisory group carefully inspected identical food displays in the booths. The displays consisted of a slice of ham with fat, a hard roll, butter, green olive near the ham, mustard, lettuce, celery, and coffee with cream. They viewed the articles critically as would kitchen employees and customers.

The first choice of the greatest number of observers favored incandescent filament lighting. It was admitted that this choice was no doubt influenced by more experience with this type of lighting. The color-improved fluorescent lamps, cool and warm white, were second and third choices. The additional red from these lamps made the resulting light compare favorably with that from incandescent filament lamps, and thereby provided a natural appearance of the various food samples. The fourth choice was the cool white fluorescent lamp.

Here and There with I.E.S. Members

FIRST PRIZE award is presented to John Jensen (right) in the Allied Arts Lighting Contest sponsored by the Arizona Section of I.E.S. for architectural students at the Arizona State University. Don Willis, Vice-President of the Arizona Public Service Co. and one of the judges of the contest makes the presentation. Subject of the competition was planning the lighting for a mythical architect's office. Second place honors were won by Lee Faulkner. In all, eight students submitted entries. Judges in the competition, which was held May 23, were Paul G. Young, President, Western Clay Products Co.; Mr. Willis, and J. D. Whitnell, of Arizona Public Service Co. and I.E.S. Vice-President of the Inter-Mountain Region.

IRREFUTABLE evidence that an error was made (May IE, p. 16A) in reporting New Orleans Section as winner of the Attendance Award at the Southern Regional Conference. The picture shows Judd Lough, Chairman of the Georgia Section, the real winner (for the fifth consecutive time) holding the plaque after its presentation. Further, the arm supporting the Speed Graphic at left belongs to the editor who goofed on the May report.

TRAINING COURSE, sponsored by the Georgia Section of I.E.S., the Georgia Power Co. and the Atlanta Chapter of the National Electrical Contractors Association, consisted of 20 sessions, two each Tuesday evening from January 10 through March 20.

See story on page 28A.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

South Pacific Coast Conference— Golden Gate Host to Biggest Regional

West Coast members had a preview of the national conference April 11-13, at the South Pacific Coast Regional Conference in San Francisco. The papers weren't the same, but they were certainly significant, and the technical program followed a similar format of symposium sessions. I.E.S. Golden Anniversary was celebrated throughout the three days, as it will be in Boston. Numerous visitors attended separate sessions of special significance to them. All phases, including the attendance of 366, contributed to an important professional meeting.

The conference was held at Hotel Mark Hopkins, famous for the view of the city's lights from the "Top of the Mark" high above Nob Hill — with the Golden Gate Section as host. Every section and Chapter in the Region was well represented with an especially large delegation from Southern California. Non-members, informed (via three advance mailings) of the importance of the five symposiums scheduled, attended in large numbers, some, of course, only for the session of particular interest to them.

The well-balanced program included sessions on Outdoor, Street, Residential, Industrial and Store Lighting. Particular emphasis was placed on the residential session, and it was one of the most stimulating and best-attended features of the conference. The program was arranged by John S. Walsh, and the conference general chairman was James E. Barnes, who headed a large and active committee. O. R. Doerr, vice president in charge of sales of the Pacific Gas and Electric Co., welcomed delegates at the opening session, with an address on the I.E.S. Golden Anniversary.

M.M.I.J.

First item on the program, which incidentally departed from the customary time and started at 2 p.m., was the contest for My Most Interesting Lighting Job. There were three entries, hotly contested, from Golden Gate, San Diego and Southern California Sections. Winner was William F. Jones, Smoot-Holman Co., Los Angeles, for the lighting of the Airesearch Division plant of Garret Manufacturing Corp. In second place were Milton C. Very and Norman Schiewe, with a design for a luminous panel to cut street reflections in a San Rafael tailor shop window. Third was Robert F. Huff, San Diego, for the relighting of a gift shop. Three Fellows of the Society served as judges in the contest: C. L. Crouch, Technical Director of I.E.S., C. M. Cutler, General Electric Co., Nela Park, Cleveland, and R. G. Slauer, Sylvania, Salem, Mass.

Special Features

The first afternoon session was completed with addresses on outdoor and tunnel lighting, details of which are given at the end of this report, and was followed by a bus tour of San Francisco area tunnel lighting installations. After dinner in Berkeley across the Bay, most delegates visited the University of California's street lighting field research station at Richmond under the guidance of Professor D. M. Finch, Regional Vice President, I.E.S. A few, however, including President and Mrs. Hartenstein chose to join in a Chinese dinner at Kan's in Chinatown, known to San Franciscans for its authentic Chinese food.

This was one of three special events for the ladies which contributed much to the success of the conference and were arranged by a committee headed by Mrs. Frank Duhme. On Thursday afternoon, after the session on residential lighting that morning, a trip by car down the Peninsula led to the garden publishing center of Sunset Magazine, California's well-known regional home and garden publication, at Menlo Park. And on Friday a brunch was held at Cliff House overlooking the Pacific, a favorite resort of San Franciscans for more than a century.

Walter Doty, editorial research director of Sunset Magazine, opened the residential session with an address, "Living With Light," in which he urged a fresh and open-eyed approach to the integration of light with decoration in the home. Such a fresh approach was the one presented by E. W. Commery of Nela Park,

Electrical West Photo

SOME of the heads responsible for the outstanding success of the South Pacific Regional Conference, taken at a breakfast committee meeting during the conference. John Walsh, national Director of I.E.S. has the floor.

MMILJ JUDGES, all Fellows of the Society, for the Regional Contest, in San Francisco. Left to right, C. M. Cutler, C. L. Crouch and R. G. Slauer.

Electrical West Photo

MMILJ WINNER William Jones, left, receives congratulations from I.E.S. President R. F. Hartenstein during San Francisco conference.

SOCIAL HIGHLIGHT at San Francisco conference was dinner-dance in honor of President and Mrs. R. F. Hartenstein (center). Flanking them at the head table are: l. to r. Mr. and Mrs. Roy Kreyser; Mr. and Mrs. Harold A. Wright; Prof. and Mrs. D. M. Finch; Mr. and Mrs. James E. Barnes; Mr. and Mrs. William Ross; and C. L. Crouch.

Electrical West Photo

I.E.S. CONFERENCE delegates visit U. of California Street Lighting Laboratory in Berkeley.

Cleveland, in his paper, "The Luminous Environment Home." This was a report on the first of a series of exploratory studies in which light is used as the primary medium for creation of mood, atmosphere, usefulness and perhaps the style of rooms. The ceiling and one wall of the test room were luminous and two walls had wall brackets providing a good flow of up and down light. These four surfaces were capable of being varied in brightness through a wide range. (For complete results of Mr. Commery's experimental room, see June 1956 I.E., p. 479.)

Architect Robert Anshen, AIA, urged that integrated illumination be sold just as built in kitchen appliances are being sold in many new tract homes today. Such a plan would make possible mass production which would bring the cost of superior lighting down, and this cost could be spread over a long period through the mortgage. Landscape Architect Lawrence Halprin, speaking on garden lighting said the trend is away from theatrical effects in quest of greater naturalness.

A gala reception for President and Mrs. Hartenstein Thursday evening was followed by dinner and dancing in the beautiful Peacock Court of the hotel. At the President's Luncheon next day, Mr. Hartenstein particularly stressed the need for 3000 new members of the illuminating profession in the next five years. The industrial and store lighting sessions, each producing talks of outstanding interest, well illustrated this need through the rapid growth in demand for lighting.

The complete program of the Conference follows:

Wednesday, April 11, 1956

Outdoor Lighting

Chairman — Roy H. Kreyser, Southern California Section.
The I.E.S. Golden Anniversary — G. R. Doerr, Vice-President, Pacific Gas & Electric Co., San Francisco.
My Most Interesting Lighting Job Competition. Judges: C. L. Crouch, C. M. Cutler, R. G. Slaser.
New Ideas in Architectural and Building Floodlighting — William Shalda, President, Shalda Mfg. Co., Burbank.
Lighting for Outdoor Parking Areas — A. L. Prior, Traffic Safety Engineer, Southern California Edison Co., Los Angeles, Calif.
A New Approach to Highway Tunnel Lighting — Harold Skootsky, John Brass, Engineers, California State Highway Dept., San Francisco; Gilbert A. Trosper, Street Lighting Engineer, Pacific Gas & Electric Co., San Francisco.

Street Lighting

Chairman — D. M. Finch, Golden Gate Section.
Inspection Tour Tunnel Lighting.
Street Lighting Dinner — Spenger's Fish Grotto, Berkeley.
Inspection Tour, U. C. Field Station — Richmond and Richmond-San Rafael Bridge.

Thursday, April 12, 1956

Residential Lighting

Chairman — Carleton J. Bunce, San Diego Chapter.
Living With Light — Walter Doty, Director of Editorial Research, Sunset Magazine, Menlo Park.
Residential Lighting Design — Robert Anshen, A.I.A., Anshen and Allen, Architects, San Francisco.
Lighting for Outdoor Living — Lawrence Halprin, Landscape Architect, San Francisco.
The Luminous Environment Home — E. W. Conseeer, Executive Engineer, General Electric Lamp Department, Cleveland.
Panel Discussion.

Regional Activities Luncheon

Chairman — D. M. Finch, Regional Vice-President.

Industrial Lighting

Chairman — William Ross, Mother Lode Chapter.
Light and Vision on the Production Line — C. L. Crouch, Technical Director, Illuminating Engineering Society, New York.
Light Sources for Industry — R. G. Slaser, Executive Engineer, Sylvania Electric Products Inc., Salem, Mass.
Lighting the Rocketdyne Aviation Plant — J. S. Hamel, Consulting Engineer, Burbank.
Keeping Footcandles Up — Roy Jones, District Engineer, Westinghouse Lamp Division, Los Angeles.
175 Foot Candles Luminous Ceilings for Industry — Thomas Allinson, Division Manager, Beckman Instruments Co., Richmond.
Panel Discussion.

Thursday Evening

President's Reception and Dinner.

Electrical West Photo

SECTION CHAIRMEN fraternizing at the South Pacific Coast Regional Conference. l. to r. Bill Ross, Mother Lode; Roy Kreyser, Southern California; Harold Wright, Golden Gate.

Friday, April 13, 1956

Store Lighting

Chairman — George E. Nimmo, San Jose Chapter.
Light Creates Environment for Sales — C. M. Cutler, Executive Engineer, General Electric Lamp Department, Cleveland.
Lighting the Shopping Center — Reginald Raetze, A.I.A., Vice-President, Welton Becket and Associates, San Francisco.
Luminous Store Front Displays — M. R. Mansshardt, Vice-President, Electrical Products Corp., Oakland.
Store Lighting Electrical Design — Clyde E. Bentley, Consulting Engineer, San Francisco.
Panel Discussion.

President's Luncheon

Chairman — Harold Wright, Golden Gate Section.
Presentation of Awards "My Most Interesting Lighting Job" — R. F. Hartenstein.
President's Address — R. F. Hartenstein, President, Illuminating Engineering Society.

Ladies' Program

Wednesday, April 11, 1956

Registration — Lobby, Mark Hopkins
Dinner — Chinabeach — Johnny Kan's

Thursday, April 12, 1956

Residential Lighting — Room of the Doves
Trip to Sunset Magazine — Menlo Park
Reception for President and Mrs. Hartenstein — Room of the Doves
Dinner-Dance — Peacock Court

Friday, April 13, 1956

Brunch — Cliff House

Conference Personnel

Regional Vice-President — Prof. D. M. Finch
General Chairman — James E. Barnes
Assistants — Charles D. Buchanan, Harold A. Wright
Regional Reception — H. H. Richmond, W. F. Bear
Program and Papers — John S. Walsh
Finance — John Keyes
Attendance — C. W. Mace
Hotel and Arrangements — R. L. Sweeet
Reception and Registration — Frank L. Dubois
Women's Program — Mrs. Frank L. Dubois
Transportation — Milton Very
Publicity — Harry McMasters

IES Promoted at New England Electrical Show

Under the direction of Samuel Silberberg, Chairman of the Publications Committee of the New England Section, a booth for the Society was sponsored at the 13th Annual Electrical Trade Show of the Electrical Manufacturers Representatives Club of New England, at Mechanics Building, Boston, May 2-4.

The booth, which stimulated many inquiries about I.E.S. was manned by Mr. Silberberg, F. E. Winslow, E. Quintiliani, Fred Vorlander, L. A. Bean, W. L. Ball, H. W. Crafts, E. Frost, N. E. Tirehurst, H. J. Wilson, L. Goetz and A. Fitzgerald.

In addition to information on the Society's publications, the booth publicized the Golden Anniversary Conference to be held in Boston this September.

Northwest Regional Conference, Spokane, Features Top Speakers from Both Coasts

Spokane, Washington newspapers hit a bonanza in good copy for three days running, April 19 through 21. Their double column heads for editions published each of those days, reflect the value of the program presented by I.E.S. Northwest Regional Conference held at the Davenport Hotel there.

"New Wonders in Light Described" refers to the discussions of new light sources presented by Willard C. Brown of General Electric, Nela, and Richard G. Slauer of Sylvania, Salem. Delegates to the conference, numbering 212, as well as the Press, were impressed with demonstrations of the latest things from the lamp labs and the possibilities of further progress in lighting application with these new sources.

"Expert Talks on Disneyland" was the *Chronicle's* head for a most interesting paper by J. S. Hamel who was a consulting engineer on the construction of Disneyland in Los Angeles. This described lighting techniques and problems encountered in this project.

"More Powerful Lighting Seen Deterrent to Crime" brought home to the readers strides being made in street lighting research, as outlined by D. W. Morrill, Line Material Co., Milwaukee. Conference delegates, however, heard the whole paper as well as his interesting approach, i.e., emphasis on higher levels of street lighting to prevent crime and accidents. He noted especially that merchants are now considerably interested in new street lighting, because of its advertising value. Window displays are brighter and attract greater night interest in areas having higher street lighting levels.

New lighting trends in various fields, featured on the I.E.S. program, also attracted the interest of the Press. Quite a few column inches in Spokane papers went to J. Roy Jones' discussion of "Office Lighting Trends"; William Shalda, who discussed outdoor floodlighting; C. L. Crouch, Technical Director at I.E.S. headquarters, who told of researches underway on visibility in fog, especially for aircraft; Howard A. Stingle, Superintendent of Spokane's Buildings and Grounds, on school lighting, and Robert F. Hartenstein, national I.E.S. President.

M.M.I.L.J.

Apparently three women will be among the national contestants for MMILJ in Boston next September, one of them being Miss Dorothy McGregor of Vancouver, B. C., who won the Regional contest in Spokane. Her winning entry was titled "Ease of Living Home"—an area of lighting application which is catching many people's attention, as well as the contest judges.

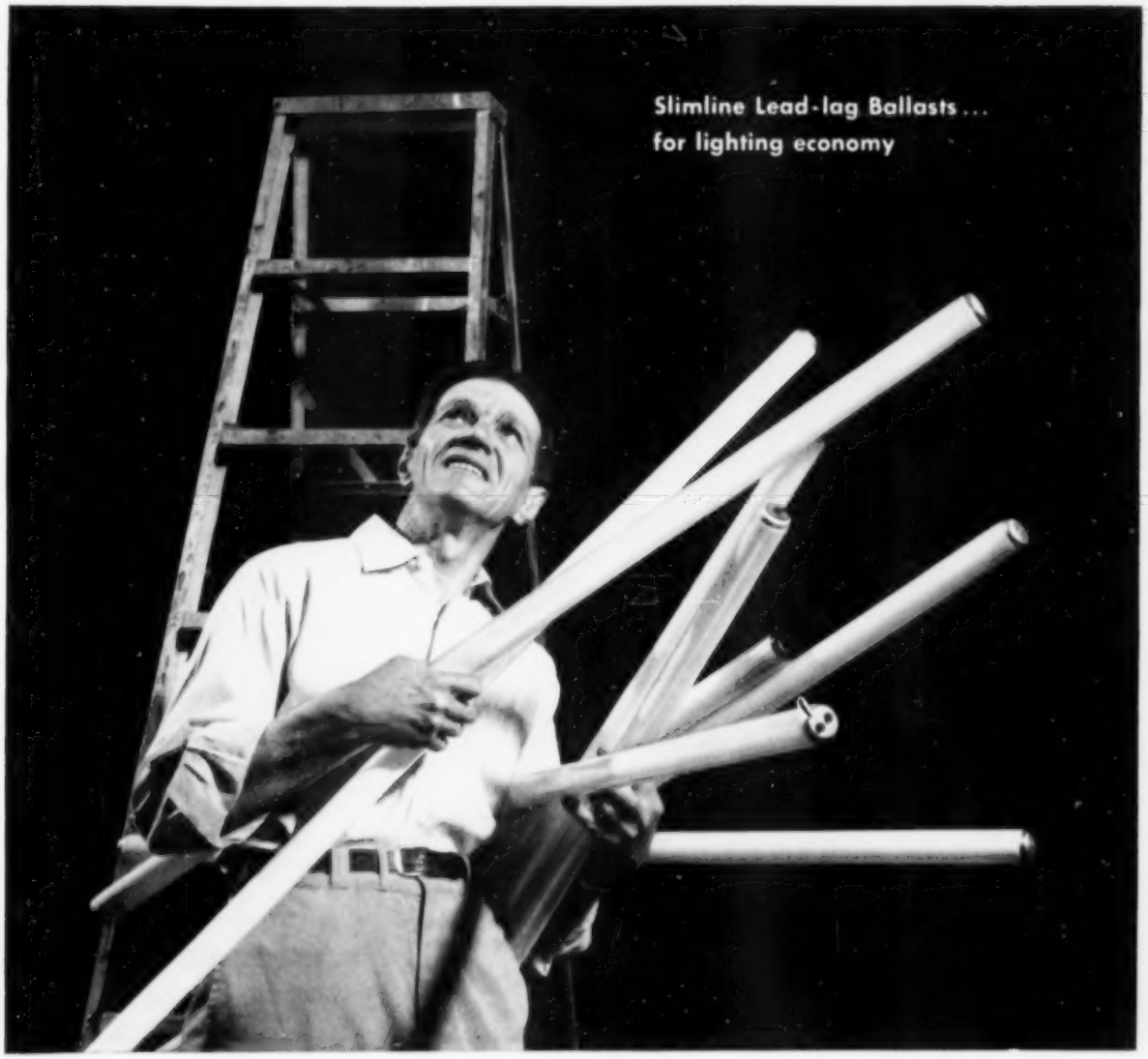
Theodore W. Beadle of the Washington Water Power Co., Spokane, took second place, with his entry on "Lighting Downtown Customer Service Center." Third place went to Jack Cottingham and Marv Prestwood of Portland. Their

(Continued on page 14A)

MEMBERSHIP attendance award of Northwest Region is received by Joseph M. Doyle, Chairman of Inland Empire Chapter, the winner. Blair Plowman, Regional V-P made the presentation.

HIGH JINKS at the Northwest Regional Conference. Eric Ackland, left, and Walter Potter, past Regional Vice-Presidents, march to the platform to the strains of the wedding march. Assisted by two other past Regional V-P's, Ken Hollingsworth and Walter Lind, they presented a "Parade of Progress" on lighting development.

REPRESENTING the Northwest Region at the National MMILJ contest will be Miss Dorothy McGregor, British Columbia Section, who is here receiving first prize for the Regional contest. President R. F. Hartenstein, left, offers his congratulations while Regional Vice-President Blair E. Plowman, at right, beams.



You can stop this costly confusion!

Here's a maintenance man with a serious problem. His job—replace a defective lamp in a lighting fixture equipped with a series slimline ballast. One lamp has burned out causing the other to burn dimly or go out completely. But which is the defective lamp—shall he guess or test. Either way, your customers lose time and money from his confusion.

You can stop this unnecessary waste by specifying Westinghouse slimline *lead-lag* ballast—when one lamp burns out the other lamp is not affected. Maintenance men know at a glance which lamp to replace. They can perform their jobs quickly and efficiently without throwing out good lamps.

And you get an extra plus with Westinghouse slimline *lead-lag* ballasts.

The exclusive UI core design means cooler, quieter, and more efficient operation. For complete details about this unique ballast, see your Westinghouse representative. Or write Westinghouse Electric Corporation, Lighting Division, Edgewater Park, Cleveland, Ohio. J-94400

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING FOR **YOU***

REGIONAL VICE-PRESIDENTS, past and present were honored at the Northwest Regional Conference, Spokane, April 19-21. l. to r. Walter Potter, Ken Hollingsworth, Walter Lind, Eric Ackland, and the current V-P, Blair E. Plowman.

(Continued from page 12A)

entry, titled "A Quarter of a Million Feet of Good Lighting Practice" covered the new office building, warehouses and service center of the Portland General Electric Co.

SOCIAL PROGRAM

With leeway of 3½ days, visiting ladies had a real whirl. Even then, they were attracted to at least three of the papers sessions (Disneyland, Progress Report and Outdoor Applications), which they attended in large numbers. Mrs. David Mozes was chairman of the ladies' activities, with a committee of eight I.E.S. wives who served as hostesses for the several events planned for the program. Mrs. Blair Plowman, wife of the Regional Vice-President was hostess for the Coffee Hour each day; Mrs. John Ruffatto and Mrs. Ted Beadle conducted a tour of Spokane; a luncheon and style show was enjoyed under the direction of Mrs. Walter Haspedis and Mrs. Joseph Doyle. All arrangements were handled by Mrs. George Romans, Mrs. John Adams, and Mrs. Edward E. Ralph.

The whole conference, ladies and gentlemen, joined in a cocktail party Thursday evening, followed by the President's Banquet and entertainment. The Banquet was a great moment for the several winners of awards, MMILJ, already mentioned, and membership and attendance (Inland Empire Chapter for the second time). President Hartenstein came in for an award too—from a group of 20 members from Calgary and Edmonton, Alberta. Western Canadians traditionally attend the Northwest Conferences in large numbers. This year they came in strength, bearing gifts. Don Frost, leader of the Calgary delegation presented Mr. Hartenstein with a ten gallon hat, Alberta style.

As a gift from the Pacific Northwest Region, Mr. and Mrs. Hartenstein also received a Myrtlewood salad bowl set. This beautiful wood is grown only in two places in the world, the state of Oregon and the Holyland, a circumstance for which members of the Inland Empire have just cause for pride.

MYRTLEWOOD salad bowl set, gift of Northwest Region, is presented by Blair Plowman, right, to President R. F. Hartenstein.

One picture being worth 5000 words, the outstanding success of this conference can undoubtedly be gathered from a glimpse at the accompanying illustrations. For the record, however, all papers presented are listed below:

Thursday, April 19

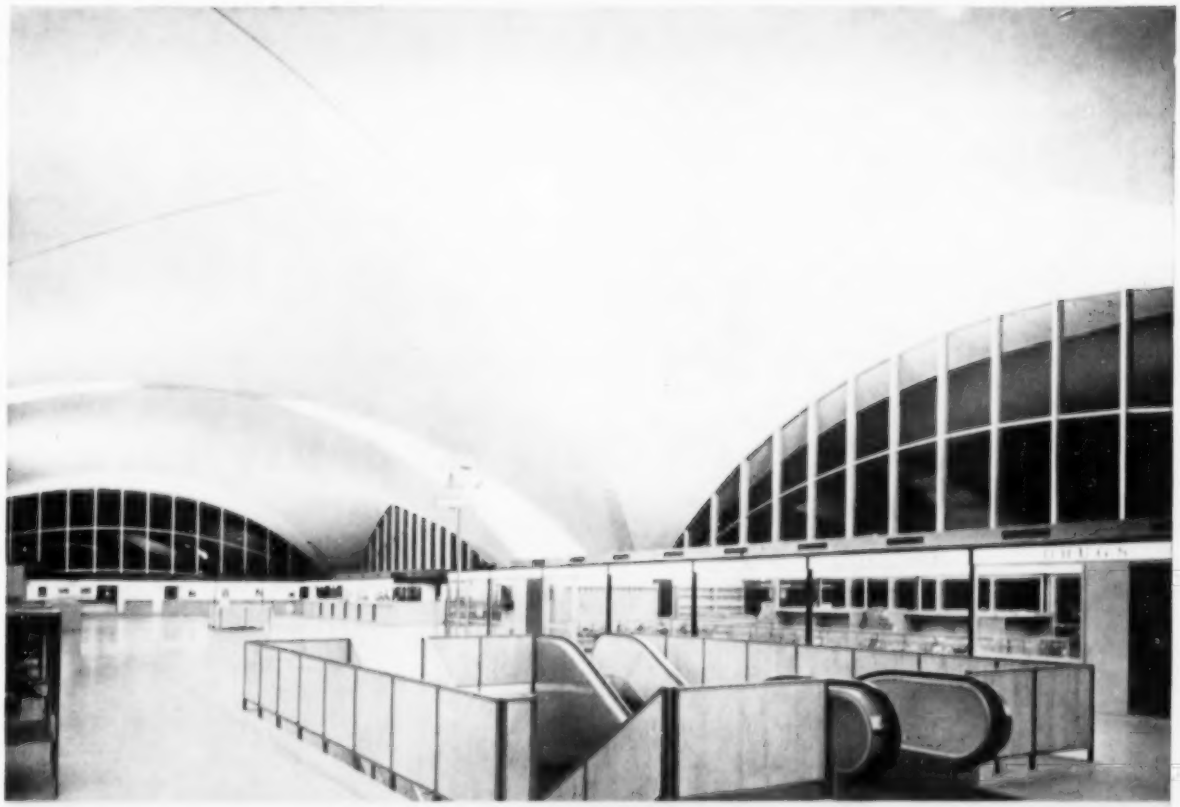
Morning Session—Joseph M. Doyle, Chairman
General Conference Chairman, John Ruffatto
Pacific Northwest Regional Vice-President, Blair E. Plowman
I.E.S. President, R. F. Hartenstein
Light Sources—Willard Brown, General Electric Co., Cleveland, Ohio
Afternoon Session—J. H. Gilbreath, Chairman
Office Lighting—J. Roy Jones—Westinghouse Electric Corp., Los Angeles, Calif.
Panelescent Lighting and Other Sources—R. G. Slauer, Sylvania Electric Products, Inc., Salem, Mass.
Lighting in the Spokane Schools—H. A. Stingle, School District #1, Spokane
Cocktail Party
President's Banquet

TEN GALLON hat, Alberta style, is sported by President Hartenstein, right, gift from the City of Calgary and the I.E.S. Calgary Study Club. Don Frost, left, leader of the 20-man Alberta delegation and Calgary Study Club made the presentation. Ten members from Edmonton and ten from Calgary study clubs attended the conference. Both groups have recently applied for charters to become chapters of I.E.S.

Friday, April 20

Morning Session—Donald W. Edmundson, Chairman.
Technical Aspects of Society and Research Program—C. L. Crouch, Technical Director, Illuminating Engineering Society
My Most Interesting Lighting Job Contest
Pacific Northwest Section and Chapter Winners:
British Columbia Section—Dorothy McGregor, British Columbia Electric Co. Inc. "Ease-of-Living Home."
Inland Empire Chapter—Ted Beadle, Washington Water Power Co. "Lighting the Downtown Customer Service Center."

(Continued on page 17A)



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(Continued from page 14A)

Vancouver Island Chapter—G. J. Roper, British Columbia Electric Co., "Some Aspects of Residential Lighting."
Puget Sound Section—Robert E. Jones, Sunbeam Lighting Co., "Lighting the Washington State Office Building, Olympia."
Oregon Section—Jack Cottingham and Mary Prestwood, Portland General Electric Co., "A Quarter of a Million Feet of Good Lighting Practice."
Afternoon Session—G. Donald King, Chairman.
European Developments—Willard Brown, General Electric Co.
New Ideas in Architectural Floodlighting and Area Lighting—William Shalda, Shalda Manufacturing Co.
Lighting of Disneyland—J. S. Hamel, Electrical Engineer, Burbank, Calif.

Saturday, April 21

Morning Session—G. F. Evans, Chairman.
The Effect of I.E.S. on Street Lighting—Dean Morrill, Line Materials Co.
Parade of Progress—Walter Potter, Chairman; Eric Ackland, Ken Hollingsworth and Walter Lind.
Awards to winners of "My Most Interesting Lighting Job" Contest.
Award of Regional Attendance Plaque.

CREDITS

Credit should be claimed by all of the Region's five Sections and Chapters, and the personnel thereof. Direct credit for excellent jobs belongs to:

Conference Committee

General Conference Chairman—John Ruffatto
Asst Gen'l Conference Chairman—Joe Doyle
Program and Papers—Dave Moore
Publicity—George Romans
Registration—Ted Beadle
Finance—Ed Ralph
Banquet and Entertainment—John Adams
Properties—Walt Harpolis
Publication Sales—Al Carlson
Ladies Program—Florence Moore

Regional Officers

Blair E. Plowman—Regional Vice President

British Columbia Section

Chairman—J. H. Gilbreath
Secretary—E. N. Kolbaine

Inland Empire Chapter

Chairman—Joseph M. Doyle
Secretary—Edward E. Ralph

Oregon Section

Chairman—Donald W. Edmondson
Secretary—Dwayne F. Seely

Puget Sound Section

Chairman—G. Donald King
Secretary—Charles R. Nelson

Vancouver Island Chapter

Chairman—A. C. F. Evans
Secretary—G. R. F. Geddie

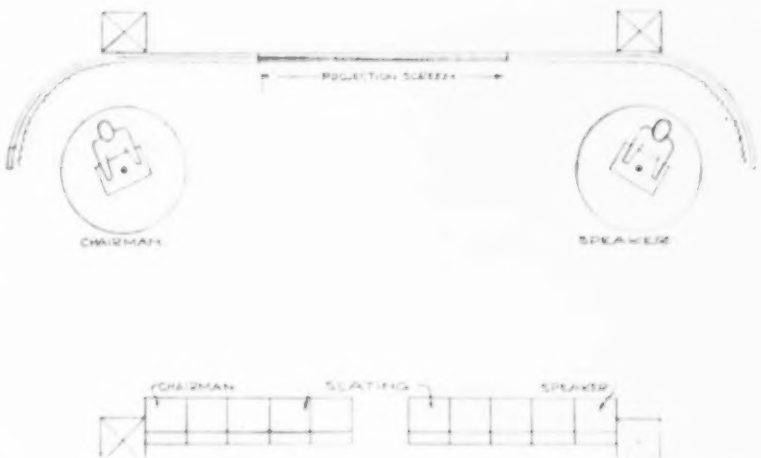
Great Lakes Regional Conference— Toledo Is Host, May 6-8

Talent for conducting Regional Conferences crops up all over the country, as those who visit all of them can testify. Great Lakes has one ace in its sleeve, however. That is its method of lighting and staging its conference room. Really good lighting for conference rooms, even those for I.E.S., is relatively unusual. Devoting talent, thought and money to the staging of technical papers is really unusual. A special Committee for Lighting Display and Decorations, with H. Creston Doner as Chairman, developed especially interesting techniques in this connection (see cut).

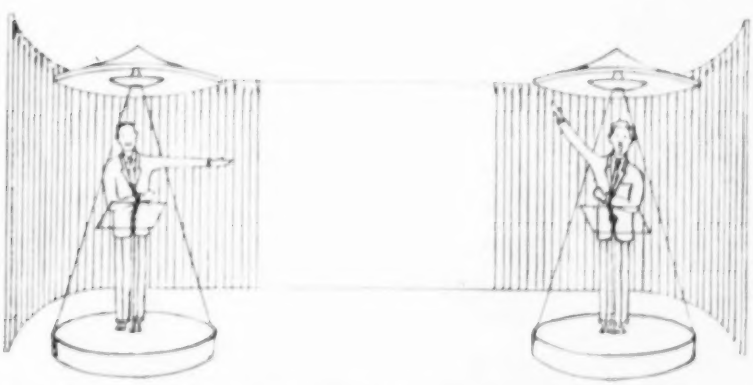
To begin with, they felt that one noticeable, and undesirable, characteristic of large meetings is that the bulkiness of the lectern hides much of the speaker. Many times only his head and shoulders are visible to the audience. So for their conference at the Commodore Perry Hotel, Toledo, they built their own lectern of transparent plastic supported by a single metal pole. Further, there were two lecterns, one on each side of the stage, so that the chairman, using one, could introduce his speaker, who was then immediately in place at the other position. No tripping over cords, no apologies for embarrassing delays as he scrambled over other speakers to reach the lectern.

An improvised lighting device was also arranged over each lectern employing pinhole downlights. Both of these hand-made luminaires were on dimmer control. As the chairman addressed the group from the left hand podium, all house lights were off, with the exception of the downlight directly over him. As he spoke,

(Continued on page 18A)



Stage plan featured at Great Lakes Regional Conference. See text for details.



Sketch showing unique staging devised for Great Lakes Regional Conference. Light curtains alleviate usual contrast between screen and background. Dual lecterns, for chairmen and speakers, illuminated by spotlights on dimmers, concentrate audience attention in pertinent direction.

(Continued from page 17A)

the speaker took his position at the right-hand podium. At the completion of the introduction, the domelight over the chairman was dimmed and the domelight over the speaker brought up to full brilliance. This kept the audience's attention on the speaker at all times.

To avoid a distracting contrast between a white screen (for lantern slides) and the inevitable dark background, the screen was flanked on each side by white draperies hung from Unistrut and arranged in a curving semi-circle at the back of the stage. For an additional decorative note, a Colorama of changing colored floodlights behind the translucent draperies and the screen were directed to the lower part of the curtain, "painting" the drapery and screen with a subtly changing variety of colored light. When the speaker started his slide presentation, the background lights were turned off, and the domelight overhead gradually dimmed out. As each slide presentation is completed, the domelight over the speaker is again brought up to full brilliance.

Robert Taylor, General Chairman, steps down from podium after introducing speaker. Light on his podium is now dimmed.

Speaker, in this case Dr. W. J. Arner, is in place after introduction, and light over his podium (on dimmer) is raised to full brilliance. Platform is plywood covered with marbelized wallpaper.

Seven contestants for MMILJ, with their chairman, H. E. Carney, are: l. to r. front row, George Seiter (first prize), J. J. Harrington, Jack Felkey, Rose Coakely, Leonard Gussow. Back row, Mr. Carney, Norman Kreidel (proxy for Rochester entry) and Donald Brown.

Lest one think the staging was the only, or even the chief feature of this conference, be assured quickly that other phases of it were equally successful. There were, for instance, no less than seven contestants for "My Most Interesting Lighting Job"; excellent (and well attended) papers sessions including an outstanding panel on school lighting from several viewpoints; a keynote address by the Mayor of Toledo; a full-scale ladies' program; a wonderful party. And an attendance of over 200 people.

The School Lighting Forum attracted a number of non-member visitors. This was a four-way debate by an architect, a lighting man, a flatglass man and a glass block man, with considerable audience participation. Professor Everett M. Strong was moderator, an unexpected replacement for Professor Paul Seagers, who was grounded in Indianapolis. Scheduled as a two-hour event, this panel stimulated the audience to overtime questions well into the late afternoon.

M.M.I.L.J.

Winner over seven good entries in the contest for My Most Interesting Lighting Job was George Seiter, of Cincinnati Gas & Electric Co., of the Ohio Valley Section, who thus qualifies to compete with the nine other Regional winners at Boston. Mr. Seiter's job was the floodlighting of the Cincinnati Gas and Electric Building, and presented unique solutions to several lighting problems.

Second prize went to Rose Coakley, General Electric Co., Cleveland Section, home lighting.

Third prize was awarded to Leonard Gussow of Michigan Section, lighting a post office.

Four other entries which made it very tough for the judges were: Donald Brown of Syracuse, N. Y., representing the Central New York Section with a gasoline filling station job. Fred Vanderlinde, of Rochester Section, lighting private offices. James J. Harrington, Western New York Section, lighting the Buffalo AAA Office. Jack Felkey, Northwest Ohio Section, relighting an old bank.

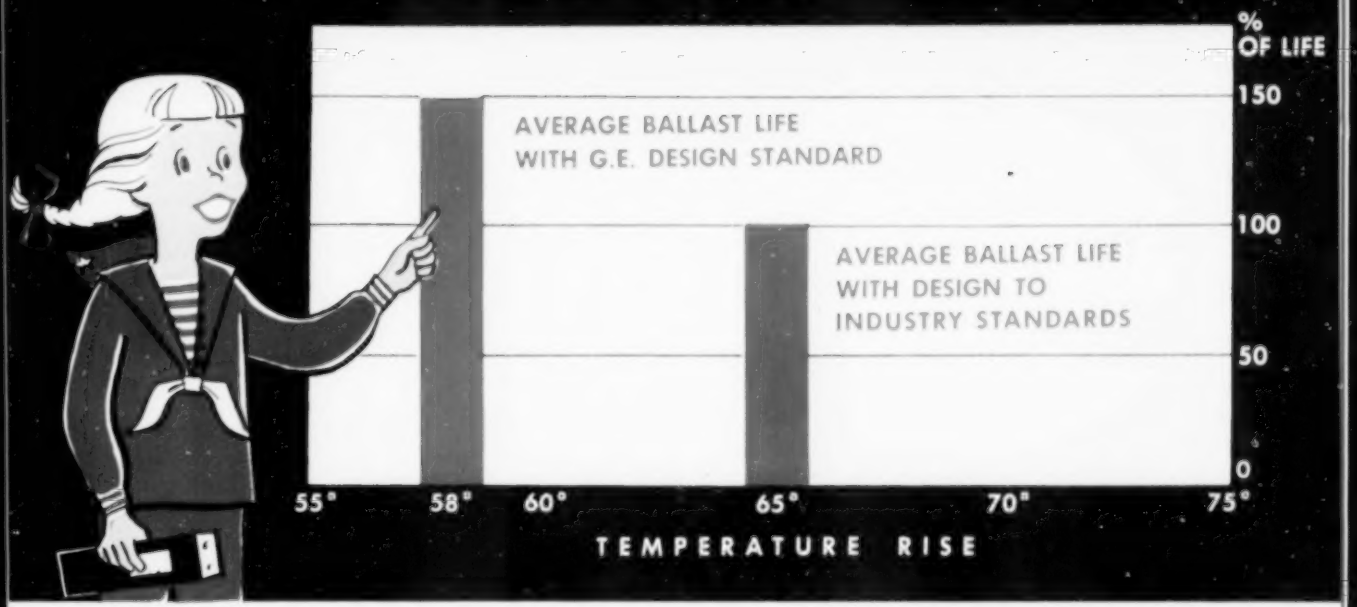
H. E. Carney was Master of Ceremonies for the Contest. Judges were R. F. Hartenstein, M. N. Waterman, and Nelson Warner.

Other Events

One aspect of the Great Lakes Regional meeting of considerable importance to future operation was the Regional Activities meeting held the day before the opening session. Incoming and outgoing officers from all of the nine Sections and

(Continued on page 20A)

G.E. gives you 50% more ballast life by designing 10% cooler than industry standards



BECAUSE G-E BALLASTS ARE engineered to operate 10% cooler than industry standards, they offer 50% longer life in your fluorescent installation. With this chart, Flora shows you the extra ballast life you get when you specify General Electric's cooler operating ballasts.

Flora* shows you why . . .

General Electric Ballasts Last 50% Longer, Help You Save Lighting Dollars

Every G-E ballast is designed to operate 10% cooler than industry standards; the chart above shows that this means 50% longer ballast life! To you, this means longer life for your fluorescent installations and a real saving in lighting dollars.

By carefully filling each ballast with a special heat-conducting compound, and by using larger wire size in the coil windings than would be required simply to meet industry standards, G-E builds ballasts that operate cooler! Cooler operating temperatures combined with the use of unusually strong insulating materials results in years of added ballast life.

These special G-E techniques contribute toward lower operating temperatures, resulting in 50% longer ballast life.

Next time you specify equipment for a fluorescent lighting installation, make sure you get the best . . . specify General Electric longer-life ballasts.

A G-E ballast tag or sticker on your fixture is proof that it's equipped with a superior ballast; G-E ballasts in your installation mean better, more efficient lighting, more economical operation. For further information on G-E ballasts, write Section 401-10, General Electric Company, Schenectady 5, New York.

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G-E BALLASTS ARE constantly spot-checked for normal or abnormal temperature rise in this special lab. Close control of temperature rise helps assure 50% longer G-E ballast life.

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Progress Is Our Most Important Product

GENERAL ELECTRIC

Still to Come

Reports on the Regional Conferences in Salt Lake City, Quebec and Washington will appear in a subsequent issue of I.E.

(Continued from page 18A)

Chapters within the Region met, under the chairmanship of A. C. Sangster, Regional V.P. The 22 items on the agenda, ranging from budget problems, to nominations for Fellow — to name a few — were thoroughly covered.

Serious, and worthwhile, as the entire conference program was, fun was not overlooked. The Ladies Committee, under Mrs. H. E. Carney as general chairman, planned a full program. A special suite was reserved for their meetings, and was used for brunch, coffee hours, and general planning. Scheduled trips included a Beauty Clinic, with models showing new ideas on hair styling, make-up, and millinery. They also went in a group for lunch at the Toledo Museum of Art and toured the galleries afterward. At most of their events, door prizes went home with a lucky few, favors with all.

The social program also included a wonderful party. This was planned by Robert Colgan who put over, very successfully, an Hawaiian flavor, with palms, leis, and appropriate music. The dance was, of course, preceded by a reception and banquet honoring President and Mrs. Hartenstein. Chairman of this "session" was Bob Taylor, who presented to the President and his wife, a portable television set as a gift from the Great Lakes Region.

PROGRAM DETAILS

For the record, complete details of the papers, and committee personnel are listed below:

Portable television set (held by Bob Taylor, general chairman) is presented to President and Mrs. Hartenstein as gift from the Great Lakes Region.

May 7 — Morning Session

Chairman — R. M. Taylor, Northwestern Ohio Section.
Invocation — The Rev. Arthur W. Hargate, Trinity Episcopal Church.
Welcome to Toledo — Mayor Ollie Crehsta.
President's Report — Robert F. Hartenstein.
"My Most Interesting Lighting Job" Contest — Chairman, H. E. Carney, Northwestern Ohio Section.

May 7 — Afternoon Session

Chairman — L. G. Thompson, Western Michigan Section.
Discussion Organizer — F. L. Fairchild, Michigan Section.
Church and Auditorium Lighting — Edward Rambusch, Rambusch Lighting Co.
School Lighting Forum — Moderator — Prof. F. M. Strong, Cornell University, proxy for Dr. Paul Seagers, University of Indiana.
An Architect — E. M. Smith, A.I.A.
A Lighting Man — Richard Bradley, Bradley Lighting Inc.
A Flatglass Man — W. J. Arner, Libbey-Owens-Ford Glass Co.
A Glass Block Man — R. C. Kendall, Owens-Illinois Glass Co.
President's Reception and Banquet
Contest Awards
Entertainment
Dinner and Dancing

May 8 — Morning Session

Chairman — W. S. Barclay, Rochester Section.
Discussion Organizer — R. M. DeLong, Ohio Valley Section.
Office Furniture Design — Its Application and Influence — George Reinthaler, Director, Grand Rapids Office Guild.
Residential Lighting — Eugene Commery, General Electric Co.
New Developments in Fluorescent and Mercury Lamps — Marshall Waterman, Westinghouse Electric Corp.
Lunch — Speaker — S. G. Hibben, Past President I.E.S.
Commemoration of I.E.S. 50th Anniversary.

May 8 — Afternoon Session

Chairman — George Warner, Cleveland Section.
Discussion Organizer — R. F. Lyth, Western New York Section.
Visual Comfort Rating and Office Lighting Practices — James M. Ketch, General Electric Co.
Ultra Violet Application — F. W. Ready, Detroit Edison Company.
Presentation of the first three award winners in Cleveland Section's design competition for students.

CONFERENCE COMMITTEES

General Conference Chairman — R. M. Taylor

CONFERENCE EXECUTIVE COMMITTEE

Regional Vice-President — A. C. Sangster
Vice-Chairman — Kenneth Cunningham
Secretary — Richard Gross
Treasurer — H. E. Carney
Chamber of Commerce — A. C. Kruckenberber
Civic — J. W. Richards, A.I.A.

COMMITTEE CHAIRMEN

Finance — H. E. Carney
Paper and Program — A. P. Hammerstrom
Attendance and Publicity — William Tyel
Registration and Reception — William Smith
Hotel — Roy Cross
Ltg. Display and Decorations — H. C. Doner
Ladies — Mrs. H. E. Carney
Transportation — Lyle Cole
Entertainment — Robert Colgan

GREAT LAKES REGION

A. C. Sangster — Regional Vice-President

CENTRAL NEW YORK SECTION

Chairman — Wm. McNulty, Jr.
Secretary — John J. McVey

CLEVELAND SECTION

Chairman — G. K. Warner
Secretary — J. G. Mitchell

(Continued on page 23A)

Hospitality suite for visiting ladies saw good service for brunch, coffee breaks and general meetings.

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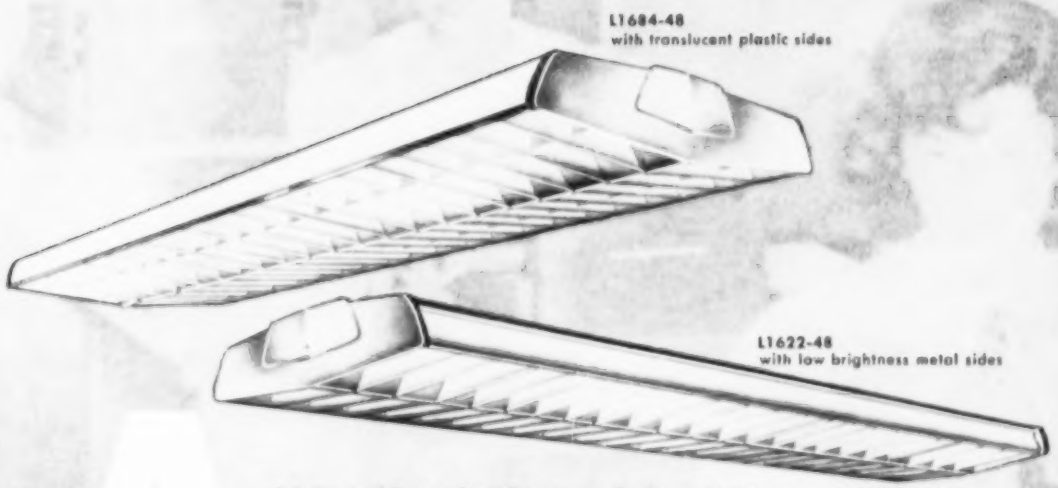

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B

B is for Board of Education members and school administrators who will be assured their decision for these Sunbeam Visionaires® will provide their student body the finest, long lasting, high quality illumination available, with maximum versatility for changing school plans.

C

C is for Contractors who will save money through the ease of installing the L1680-L1620 series, either ceiling or pendant mounted. Fixture channels accommodate sliding clamp hangers, ample knockouts provided for easy continuous row or single unit installation. Maintenance is simplified by chain-suspended cover and louver; lamps can be changed from a single position.

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UMC universal manufacturing corp.

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(Continued from page 20A)

MIAMI VALLEY CHAPTER
Chairman ..... D. R. Hughes, Jr.
Secretary ..... D. C. Fieberger

MICHIGAN SECTION
Chairman ..... Edward L. Fairchild
Secretary ..... Earl Domoney

NORTHWESTERN OHIO SECTION
Chairman ..... A. P. Hammerstrom
Secretary ..... E. J. McGinnis

OHIO VALLEY SECTION
Chairman ..... B. M. DeLong
Secretary ..... E. J. McGinnis

ROCHESTER SECTION
Chairman ..... Wm. S. Barclay
Secretary ..... Miss M. Franklin

WESTERN MICHIGAN SECTION
Chairman ..... L. G. Thompson
Secretary ..... D. A. Harper

WESTERN NEW YORK SECTION
Chairman ..... Willard E. Hayes
Secretary ..... F. R. Pfalzgraf

I.E.S. Officers Elected For Year 1956-1957

At a meeting of the I.E.S. Council held June 14, 1956, the report of the Committee of Tellers was presented, giving the results of the recent election of officers for the coming year, beginning October 1, 1956. The following have been elected to the offices indicated.

GENERAL OFFICERS

President — M. N. Waterman, Westinghouse Electric Corp., Bloomfield, N. J.

Vice President — George J. Taylor, Day-Brite Lighting Inc., New York, N. Y.

General Secretary — Richard G. Slager, Sylvania Electric Products Inc., Wheeling, W. Va.

Treasurer — J. B. Browder, Georgia Power Co., Atlanta, Ga.

Directors (Until 1959) — A. C. Sangster, Detroit Edison Co., Detroit, Mich.; C. W. McCormick, Connecticut Light & Power Co., Hartford, Conn.

Regional Vice Presidents — *Great Lakes Region*, R. M. Taylor, The Toledo Edison Co., Toledo, Ohio; *Midwestern Region*, J. A. Schneller, Lighting Products Inc., Highland Park, Ill.; *Northeastern Region*, C. E. Waldron, Niagara Mohawk Power Corp., Albany, N. Y.; *Pacific Northwest Region*, Kenneth Reid, Corp. of the City of Victoria, Victoria, B. C.; *South Pacific Coast Region*, Carleton M. Thompson, San Diego Gas & Electric Co., San Diego, Calif.

ALABAMA SECTION

Chairman — W. J. Pettyjohn, Westinghouse Electric Corp., Birmingham, Ala.

Vice Chairman — J. T. Keyser, Alabama Power Co., Birmingham, Ala.

Secretary — W. C. Martin, Jr., Alabama Power Co., Birmingham, Ala.

Board of Managers — F. H. Britton, Jr., Sam Davidson, Donald G. Hallmark, E. B. Richey.

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Chairman — John F. Gohring, J. E. Redmond Supply Co., Phoenix, Ariz.

Vice Chairman — J. R. Williams, Arizona Public Service Co., Phoenix, Ariz.

Secretary — Robert E. Tweedy, 914 W. Madison St., Phoenix, Ariz.

Board of Managers — A. W. Brown, R. W. Godemann, Marriel Hamilton, John A. Ware, Jr.

BRITISH COLUMBIA SECTION

Chairman — D. S. Gordon, B. C. Electric Co. Ltd., Vancouver, B. C.

Vice Chairman — P. F. Fletcher, Canadian General Electric Co., Ltd., Vancouver, B. C.

Secretary — A. Anderson, British Columbia Electric Railway Co., Vancouver, B. C.

Board of Managers — A. H. Cocking, F. G. Crompton, H. G. Foster, M. M. Hawkey.

LIGHTING CALENDAR

Society Events

September 17-21, 1956 — Illuminating Engineering Society, National Technical Conference, Hotel Statler, Boston, Mass.

September 9-13, 1957 — Illuminating Engineering Society, National Technical Conference, Biltmore Hotel, Atlanta, Ga.

Industry Events

October 1-5, 1956—American Institute of Electrical Engineers (Fall General Meeting); Morrison Hotel, Chicago, Ill.

October 2-4, 1956—Canadian Electrical Manufactureres Association (12th Annual Meeting); Sheraton Brock Hotel, Niagara Falls, Ontario, Canada.

October 7-12, 1956 — Society of Motion Picture and Television Engineers, Ambassador Hotel, Los Angeles, Calif.

October 15-16, 1956 — United States Committee, International Commission on Illumination, Nittany Lion Inn, State College, Pa.

October 18-20, 1956 — Optical Society of America, Lake Placid, N. Y.

October 22-24, 1956 — American Standards Association, 38th Annual Meeting (In conjunction with Seventh National Conference on Standards), Hotel Roosevelt, New York, N. Y.

October 22-26, 1956—National Safety Council, 44th National Safety Congress & Exposition, Chicago, Ill.

November 12-16, 1956 — National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

January 21-25, 1957 — American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler, New York, N. Y.

February 17-20, 1957 — National Electric Sign Association, Annual Convention and Exhibit, Sheraton Park Hotel, Washington, D. C.

March 11-14, 1957 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

May 6-8, 1957 — Air Conditioning and Refrigeration Institute, Annual Meeting, The Homestead, Hot Springs, Va.

May 7-9, 1957 — Chicago Electrical Industry Show, Chicago, Ill.

June 24-28, 1957 — American Institute of Electrical Engineers, Summer General Meeting, Montreal, Que.

August 28-30, 1957 — American Institute of Electrical Engineers, Pacific General Meeting, Yakima, Wash.

October 7-11, 1957 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 21-25, 1957 — National Safety Council, 45th National Safety Congress & Exposition, Chicago, Ill.

November 11-15, 1957 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

CAPITAL SECTION

Chairman — Harold V. Oerting, Potomac Electric Power Co., Washington, D. C.

Vice Chairman — S. W. Charlesworth, General Electric Supply Co., Washington, D. C.

Secretary — A. J. Rugo, Sylvania Electric Products Inc., Alexandria, Va.

Board of Managers — Arthur Bigelson, Thomas F. Coghlan, Benjamin Goodman, Robert M. Lowry.

CENTRAL NEW YORK SECTION

Chairman — E. L. Moyer, Malcolm R. & Edwin L. Moyer, Syracuse, N. Y.

Vice Chairman — J. J. McVey, Niagara Mohawk Power Corp., Syracuse, N. Y.

Secretary — J. S. Haney, Crouse-Hinds Co., Syracuse, N. Y.

Board of Managers — J. K. Blair, Robert Caryl, R. W. Jani, William McNulty, Jr.

CHICAGO SECTION

Chairman — Eric H. Church, Lighting Products Inc., Highland Park, Ill.

Vice Chairman — Willis F. Carson, Commonwealth Edison Co., Chicago, Ill.

Secretary — Carl F. Jensen, Westinghouse Electric Corp., Chicago, Ill.

Board of Managers — R. J. Diefenthaler, J. T. McLaughlin, Louis Rosenstein, L. H. Vanbermark.

CLEVELAND SECTION

Chairman — M. E. Kerk, Westinghouse Electric Corp., Cleveland, Ohio.

Secretary — C. J. Allen, General Electric Co., Cleveland, Ohio.

Board of Managers — Theodore Ake, Jr., E. I. Creed, R. W. Morris, G. C. Robinson, A. H. Stevenson, Jr.

CONNECTICUT SECTION

Chairman — Merritt Horner, 815 Chestnut Hill Road, Glastonbury, Conn.

Vice Chairman — R. D. Babcock, General Electric Co., New Haven, Conn.

Secretary — William P. Carpenter, The Superior Electric Co., Bristol, Conn.

Board of Managers — R. E. Ballard, H. S. Kelly, L. A. Senofonte, H. R. Young.

EASTERN NEW YORK SECTION

Chairman — C. D. Hollister, Niagara Mohawk Power Corp., Albany, N. Y.

Vice Chairman — Harry E. Rudman, Rensselaer Polytechnic Institute, Troy, N. Y.

Secretary — Donald W. Goodwine, Havens Electric Co., Albany, N. Y.

Board of Managers — John S. Baker, Joseph B. Foley, J. M. Harney, J. L. Ottenheimer.

EASTERN PENNSYLVANIA SECTION

Chairman — C. A. Derkeitz, Westinghouse Electric Corp., Allentown, Pa.

Vice Chairman — E. W. Kelsey, Pennsylvania Power & Light Co., Harrisburg, Pa.

Secretary — R. J. Prettyman, Reed Supply Co., Lancaster, Pa.

Board of Managers — J. B. Fritz, F. M. Hochenauer, J. L. Mellar, G. E. Parks.

FLORIDA SECTION

Chairman — George S. Jack, Rucker Electric Supplies Inc., St. Petersburg, Fla.

Vice Chairman — Raymond L. Simmons, Florida Power & Light Co., Ft. Myers, Fla.

Secretary — Gilbert H. Parker, Westinghouse Electric Corp., Chamblee, Ga.

Board of Managers — J. A. Banter, R. C. Bedford, B. F. Best, Frank Moss.

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GEORGIA SECTION

Chairman — W. M. Pearson, Graybar Electric Co., Atlanta, Ga.

Vice Chairman — W. C. Fink, Jr., 70 4th St., N. W., Atlanta, Ga.

Secretary — Thomas W. Haslam, Georgia Power Co., Atlanta, Ga.

Board of Managers — S. J. Andre, John Brun, L. J. Campbell, Judd Louis.

GOLDEN GATE SECTION

Chairman — Guy DeLoach, 224 Oak St., San Francisco, Calif.

Vice Chairman — Charles W. Marr, Pacific Gas & Electric Co., San Francisco, Calif.

Secretary — John E. Keyes, Benjamin Electric Mfg. Co., San Francisco, Calif.

Board of Managers — James E. Barnes, F. E. Dubuc, Jr., F. M. Falge, R. W. Thanen.

HEART OF AMERICA SECTION

Chairman — F. E. Miles, Frank Miles Electric Co., Kansas City, Mo.

Secretary — T. C. Sidlo, General Electric Co., North Kansas City, Mo.

Board of Managers — C. V. Dunn, H. L. Hutchinson, A. E. Seifer, Jr., N. J. Thompson, C. W. Thorsell.

INDIANA SECTION

Chairman — Denton E. Hull, C. M. Buck & Associates, Indianapolis, Ind.

Vice Chairman — Robert L. Peloquin, Westinghouse Electric Corp., Indianapolis, Ind.

Secretary — Harry W. Claffey, Jr., General Electric Co., Indianapolis, Ind.

Board of Managers — Edward M. Chellew, J. R. Colville, Jr., Leo W. Miles, Arthur H. Wiese.

IOWA SECTION

Chairman — Gale L. Williams, Iowa Public Service Co., Waterloo, Iowa.

Vice Chairman — Melvin H. Galbraith, 222 First St., N. E., Cedar Rapids, Iowa.

Secretary — William J. Vahl, Crescent Electric Supply Co., Dubuque, Iowa.

Board of Managers — R. C. Holcombe, L. D. Rafferty, W. T. Reece, Jr., LeRoy J. Widiger.

MARYLAND SECTION

Chairman — C. Edward Sparrow, Jr., Westinghouse Electric Corp., Baltimore, Md.

Vice Chairman — P. Kenneth Allen, General Electric Co., Baltimore, Md.

Secretary — Paul J. Puckett, Westinghouse Electric Corp., Baltimore, Md.

Board of Managers — Clarence J. Berry, George F. Walter, E. R. White, III, Howard M. White.

MICHIGAN SECTION

Chairman — Harry R. Robbins, General Electric Co., Detroit, Mich.

Secretary — James F. Finn, Detroit Edison Co., Detroit, Mich.

Board of Managers — Earl R. Dunmore, George S. Evans, S. A. Fatzer, A. R. Keeler, Duncan Preston.

MILWAUKEE SECTION

Chairman — William N. Linck, Linck Electric Co., Milwaukee, Wis.

Vice Chairman — W. C. Kuhnke, Wisconsin Electric Power Co., Milwaukee, Wis.

Secretary — M. H. Breitenfeldt, Wisconsin Electric Power Co., Milwaukee, Wis.

Board of Managers — B. R. Bonn, E. J. Donegan, R. F. VandenBoom, R. L. Wittenberg.

MONTREAL SECTION

Chairman — J. P. R. Cristel, The Shawinigan Water & Power Co., Montreal, Que.

Vice Chairman — D. Brooks, Shurtall Electric Co., Ltd., Montreal, Que.

Secretary — Gordon Nalo, Mitchell Mfg. Co., Montreal, Que.

Board of Managers — W. P. Beasley, A. A. Greenhough, C. E. Mertens, V. W. Stubbings.

NEW ENGLAND SECTION

Chairman — Carleton M. Holden, Champion Lamp Works, Lynn, Mass.

Vice Chairman — Walter L. Ball, Stone & Webster Engineering Corp., Boston, Mass.

MORE THAN 40 public utility engineers and electrical distributor representatives attended a 3-day conference at the Holophane Engineering Center, Newark, Ohio, in late May. A complete inspection trip through the center and factory was one feature of the meeting.

Secretary — Ralph L. Hunt, Graybar Electric Co. Inc., Boston, Mass.

Board of Managers — John F. G. Eichorn, Jr., Edward O. Kassman, Paul H. Lamson, R. W. Wilson.

NEW ORLEANS SECTION

Chairman — S. C. Berdon, New Orleans Public Service Inc., New Orleans, La.

Vice Chairman — Walter T. Faber, Louisiana Power & Light Co., New Orleans, La.

Secretary — C. C. Kleinschmidt, P. O. Box 843, New Orleans, La.

Board of Managers — Edna P. Fortier, F. M. Godat, Jr., S. H. Nolhacker, Jr., G. C. Schroeder, Jr.

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Vice Chairman — H. A. Anderson, Dorro Test Corp., North Bergen, N. J.

Secretary — R. L. Zahour, Westinghouse Electric Corp., Bloomfield, N. J.

Board of Managers — J. F. Gunther, W. H. Keen, E. R. Manning, Ira Newman.

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Chairman — Robert Colgan, General Electric Supply Co., Toledo, Ohio.

Vice Chairman — Lyle J. Cole, General Electric Supply Co., Toledo, Ohio.

Secretary — H. W. Teel, Jr., Toledo Edison Co., Toledo, Ohio.

Board of Managers — Elmer R. Brigham, Homer Ferguson, David J. Kirby, Walter H. Rochlin.

OHIO VALLEY SECTION

Chairman — Val G. McCluskey, General Electric Co., Cincinnati, Ohio.

Secretary — Fred B. MacRae, 6914 Montgomery Road, Cincinnati, Ohio.

Board of Managers — David E. Baker, R. J. Breitenstein, Robert A. Rosteck, George H. Seifer, Paul F. Stiller.

OIL CAPITAL SECTION

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Vice Chairman — W. T. Walters, Public Service Co. of Oklahoma, Tulsa, Okla.

Secretary — James C. Netherton, Jr., 3130 E. 44th St., Tulsa, Okla.

Board of Managers — Elmer W. Luebbert, Jack R. Seay, W. E. Short, T. C. Wier.

OREGON SECTION

Chairman — Dudley D. Moore, Benjamin Electric Mfg. Co., Portland, Ore.

Vice Chairman — D. E. Seely, Westinghouse Electric Corp., Portland, Ore.

Secretary — Jack T. Cottingham, Portland General Electric Co., Portland, Ore.

Board of Managers — Donald W. Edmundson, James L. Hunt, Jr., Fritz A. Klawa, John A. Schalber.

PHILADELPHIA SECTION

Chairman — W. R. Mackinney, Westinghouse Electric Corp., Philadelphia, Pa.

Secretary — Robert L. Herr, Philadelphia Electric Co., Philadelphia, Pa.

Board of Managers — T. G. Broussard, Fred N. Cooper, W. P. Graham, David D. Lees, P. B. Thorne.

PITTSBURGH SECTION

Chairman — James P. Boyden, Jr., Westinghouse Electric Corp., Pittsburgh, Pa.

Vice Chairman — James A. Hodges, James A. Hodges Co., Pittsburgh, Pa.

Secretary — J. S. Frizell, Pittsburgh Reflector Co., Pittsburgh, Pa.

Board of Managers — L. W. Hornbeck, Hugh S. James, H. S. Orton, D. C. Thomas.

PUGET SOUND SECTION

Chairman — Howard C. Hall, 405 Smith, Seattle, Wash.

Secretary — Jack H. Wells, R. T. Heinz Co., Seattle, Wash.

Board of Managers — G. Donald King, George A. Mackey, Charles R. Nelson, Elmer H. Smith, Beverly A. Travis.

ROCHESTER SECTION

Chairman — R. Bruce Thompson, 9 Lacrosse Parkway, Rochester, N. Y.

Secretary — Miss Melrose M. Franklin, Rochester Gas & Electric Co., Rochester, N. Y.

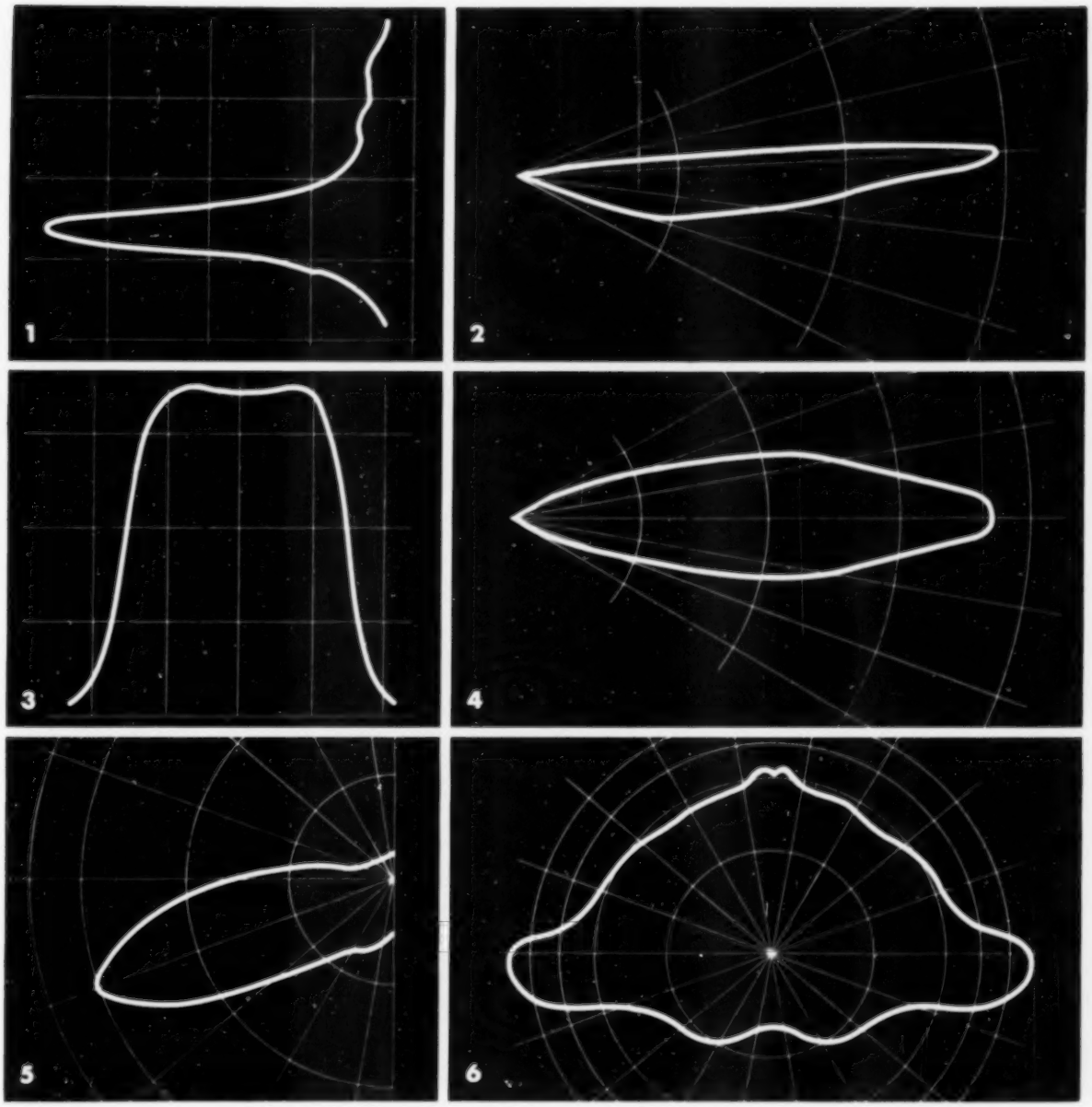
Board of Managers — William S. Barclay, R. M. Conheady, Norman T. Kridel, F. J. Schmitt, Fredric Vanderlinde.

ROCKY MOUNTAIN SECTION

Chairman — Leonard J. Carlon, Albert Sechrist Mfg. Co., Denver, Colo.

Vice Chairman — A. E. McKettrick, 8995 W. Bayaud, Lakewood, Colo.

(Continued on page 27A)



These distribution curves are all related to transportation signaling. Take a try at matching them up. There's an *airport landing light, a broadcasting tower marker, a railroad signal, a grade crossing warning, a street light, and a traffic signal.*

Can you match the curve to travel safety?

See if you can match these existing Corning lenses to their jobs.

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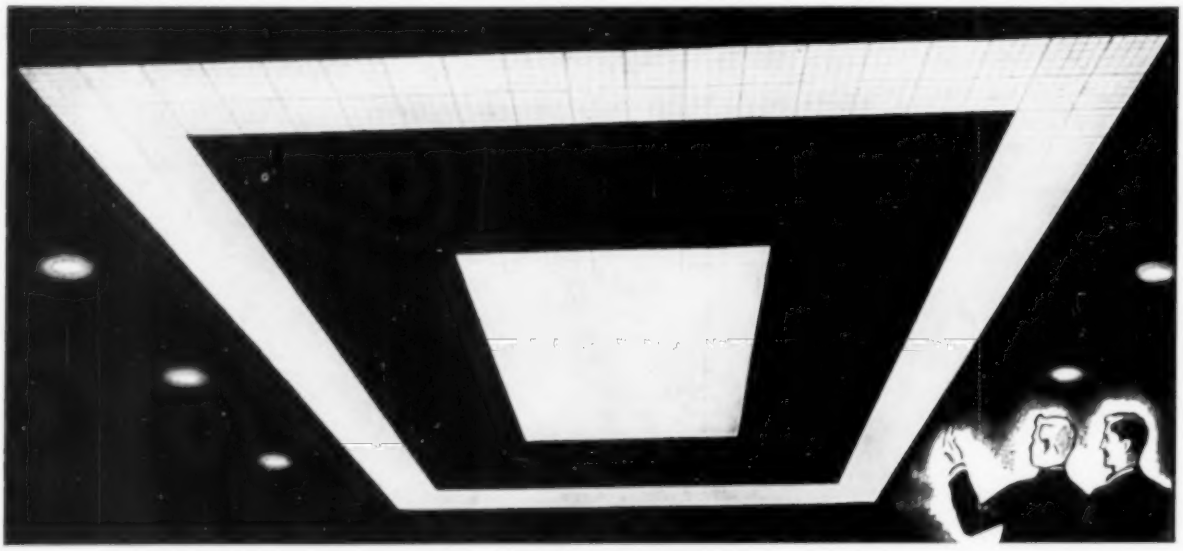

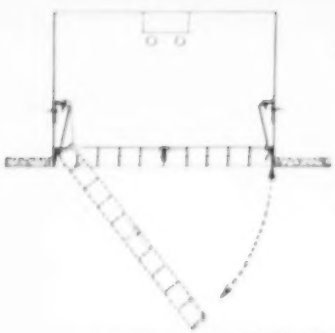

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STOCKED AND DISTRIBUTED BY LEADING DISTRIBUTORS IN THE UNITED STATES & CANADA

(Continued from page 24A)

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Vice Chairman — Richard D. Cohen, Glasco Electric Co., St. Louis, Mo.
Secretary — Charles H. Zurheide, Smith-Harlon-Zurheide-Levy, Inc., St. Louis, Mo.
Board of Managers—Henry Arendes, Brooks Chassaing, Henry J. Poehling, Ernest W. Stohlmann, Jr.

SAN JACINTO SECTION

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Vice Chairman—Arthur M. Rice, Howard & Johnston, Houston, Texas.
Secretary — John F. Dill, Sylvania Electric Products, Inc., Dallas, Texas.
Board of Managers — H. G. Hrivnatz, Richard C. Jung, W. J. Laughlin, Edward C. Oler.

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Chairman — George A. Huebenauer, Benjamin Electric Mfg. Co., Los Angeles, Calif.
Vice Chairman — Merle A. Potter, Smoot Holman Co., Inglewood, Calif.
Secretary — Roy E. Bevan, Sylvania Electric Products, Inc., Los Angeles, Calif.
Board of Managers — Harold F. Hall, B. J. Hartmann, J. Roy Jones, Roy H. Kreyser.

SOUTHWESTERN SECTION

Chairman — John B. Deck, Jr., Texas Power & Light Co., Dallas, Texas.
Vice Chairman — Thomas L. Moore, Fischbach & Moore of Texas, Inc., Dallas, Texas.
Secretary — E. L. Cole, Dallas Power & Light Co., Dallas, Texas.
Board of Managers — Arnold M. Gaynor, John Metzenthin, Charles F. Shearer, O. Reynolds Young.

TAR HEEL SECTION

Chairman — A. L. Ducker, Jr., General Electric Co., Greensboro, N. C.
Vice Chairman — James J. Cardo, Independent Electric Supply Co., Inc., Charlotte, N. C.
Secretary — James A. Lowe, Duke Power Co., Greensboro, N. C.
Board of Managers — G. C. Hough, R. C. Marshall, Jr., E. D. Stevens, G. W. Williams, Jr.

TENNESSEE VALLEY SECTION

Chairman — Joe W. Fowler, Joe Willis Factory Sales Agency, Nashville, Tenn.
Secretary — Harry W. Bourgeois, 1805 Harjes St., Nashville, Tenn.
Board of Managers — C. H. Patterson, Earl Pond, Jr., W. H. Ridley, J. L. Simpson, C. W. Sturdivant.

TORONTO SECTION

Chairman — Grant E. Davidson, Hydro Electric Power Commission of Ontario, Toronto, Ont.
Vice Chairman — John M. Chorlton, Toronto Board of Education, Toronto, Ont.
Secretary — E. Machtinger, Crouse-Hinds Co. of Canada Ltd., Toronto, Ont.
Board of Managers — A. J. Brown, D. F. Davis, A. W. Henschel, R. P. Lindsay.

TWIN CITY SECTION

Chairman — A. A. Aronson, Northern States Power Co., Minneapolis, Minn.
Vice Chairman — G. W. Frederick, General Electric Co., Minneapolis, Minn.
Secretary — F. T. Tillemans, Westinghouse Electric Corp., Minneapolis, Minn.
Board of Managers — W. E. Booth, C. H. Branham, M. H. Bruce, R. E. White.

UTAH SECTION

Chairman — Wayne F. Mulcock, Utah Power & Light Co., Salt Lake City, Utah.
Vice Chairman — F. Cyrus Bates, Bates Engineering Co., Salt Lake City, Utah.
Secretary — Earl Don Peterson, Utah Power & Light Co., Salt Lake City, Utah.
Board of Managers — William C. Brown, Robert W. Darger, Jack W. Lowder, Wayne L. Shaw.

WESTERN MICHIGAN SECTION

Chairman — W. Dale Crites, 1377 Biscayne Way, Haslett, Mich.
Vice Chairman — D. A. Harper, General Electric Supply Co., Grand Rapids, Mich.
Secretary — William Winglar, J. A. G. Dennman Co., Grand Rapids, Mich.
Board of Managers — W. T. Ryerson, Lewis L. Nurnberger, A. B. L. Shenker, E. W. Wheeler.

WESTERN NEW YORK SECTION

Chairman — Byron F. Lyth, Jr., Niagara Mohawk Power Corp., Buffalo, N. Y.
Secretary — Leo P. Gauthier, Sylvania Electric Products Inc., Buffalo, N. Y.
Board of Managers — T. E. Barhite, Jr., F. B. Burke, E. S. Burrows, W. E. Hayes, Neal Jacobus.

STUDENTS winning awards in the Southern California Section's annual Design Competition at the University of Southern California are, left to right: Delmer Beckhart, first; Marvin Taff, second; Paul Wursthoff, third; and Richard Martin, Peter Rusnak and Sheldon Caris, Honorable Mention.

Awards Presented in Student Design Competition

Presentation of Awards in the annual Design Competition for students at the University of Southern California School of Architecture took place May 2 at the regular meeting of the I.E.S. Southern California Section, which sponsors the contest in cooperation with the local A.I.A. group. This year's project was "Lighting a Small Theatre." Judges for I.E.S. were Michael J. Garris, Edward Balogh and Ted Shepherd; for A.I.A., Frank Gruys, Herman C. Light and Whitney R. Smith.

The students placed as follows:

First Prize — $100 — Delmer Beckhart
Second Prize — $50 — Marvin Taff
Third Prize — $25 — Paul Wursthoff
Honorable Mention — $10 each — Peter Rusnak, Richard Martin and Sheldon Caris

A one-year Student Membership in I.E.S. was also included in the prizes.

Van Lee Schmidt, Chairman of the evening, presented the speakers, with the following topics:

Light and Architecture — Arthur B. Gallion, Dean, USC School of Architecture.
AIA Viewpoint of the Competition — Whitney R. Smith, A.I.A.
IES Viewpoint of the Competition — Michael J. Garris, I.E.S.
Presentation of Awards — Roy H. Kreyser, Chairman, Southern California Section, I.E.S.
Lighting — the Oldest and Most Indispensable Architectural Motif — Vincent Palmer Associates, Architects and Engineers, Los Angeles.

Industrial Lighting Is Theme Of Milwaukee Spring Conference

Industrial Lighting was the theme of the eighth annual full-day Spring Lighting Conference, sponsored May 25 by the Milwaukee Section of I.E.S. The meeting was held at the Engineers Society of Milwaukee Building and started promptly at 9 a.m. with registration. Members were welcomed by I. L. Illing, Wisconsin Electric Power Co. The technical program for morning and afternoon sessions was as follows:

The Trend to Quality in Industrial Plant Lighting — S. E. Guth, Director of Lighting Research, General Electric Co., Cleveland, Ohio.
What's New in Plant Office Lighting Recommendations — W. J. Johnson, Lighting Engineer, Westinghouse Electric Corp., Cleveland, Ohio.
Inspection Lighting Technique — Richard Smart, Regional Sales Engineer, Sylvania Electric Products Inc., Melrose Park, Ill.

(Continued on page 28A)

(Continued from page 27A)

Relation of Lighting and Color to Production — L. S. Oyster, Field Manager, E. I. du Pont de Nemours & Co.

Outdoor Plant Lighting — Daniel J. O'Neill, Manager of Industrial Lighting, The Holophane Co., New York, N. Y.

Local Industrial Lighting Applications — Charles Laupp, Superintendent of special service sales, Wisconsin Electric Power Co.

Cocktail hour and buffet dinner followed the technical program. E. J. Donegan, Graybar Electric Co., was Chairman of the Conference.

Lighting Training Course Joint Georgia Project

Main project of the Educational Committee of the Georgia Section, I.E.S., this year has been the lighting training course for architects, engineers and electrical contractors, co-sponsored with the Georgia Power Co., and the Atlanta Chapter of the National Electrical Contractors Association. See photo on page 8A.

Instructors and overall planning were provided by the I.E.S. Section, (for program, see I.E. January, page 17A), solicitation of students by the N.E.C.A. group, with the utility supplying the office procedure and secretarial work necessary.

The program consisted of twenty sessions, two each week, on Tuesday evenings from January 10 to March 20, held at the YMCA in Atlanta. The tuition fee of $25 included dinner between the hour and a half sessions.

March 20 was graduation day for the 30 who received certificates for having finished the course. Members of the Section's Education Committee, who planned the course are: R. C. Bythewood, Chairman; E. Rembert DuBose; Jason W. Elrod; Jim B. Koen; Mrs. Reta Lee Hope; and Johnny Brun.

Active Maine Group Holds Extension Meeting

Another of the highly successful Extension Meetings of the New England Section was held April 5 at the Falmouth Hotel, in Portland, Maine. Local Representative Perley E. Weatherbee acted as General Chairman and Toastmaster at the dinner meeting, which was co-sponsored by I.E.S. and the Electrical Associates of Maine. The attendance of 82 included members of E.A., I.E.S., A.I.E.E., and architects, electrical contractors, plant engineers, school superintendents and lighting specialists.

Lawrence S. Cooke, General Electric Co., was featured speaker, discussing what's new in the application and design of lamps.

Operation I.E.S.

Office Lighting Practice

Another I.E.S. Recommended Practice has just been published, in the June issue of ILLUMINATING ENGINEERING. This latest Practice covers Office Lighting, superseding the previous one published nine years ago, in 1947. Every member of the Society should seek a quiet spot (preferably at home) and seriously study the contents of this report. Major changes in office lighting technique and applications are presented in it.

The current practice emphasizes the importance of light and paint conditioning. Comfort of seeing is stressed, with a new method of evaluating this comfort by graphical means.

Revision of the 1947 Office Lighting Practice was started some five or six years ago under the chairmanship of R. L. Oetting. The job then passed on to G. P. Wakefield and subsequently was completed by J. J. Neidhart. During all this time, G. F. Dean was Vice-Chairman. He did a most commendable job on this committee, rendering a splendid service to the Society and the lighting industry at large.

When consideration was first given to revising the 1947 Practice, there were six members on the committee. During the serious stages of revision, the committee consisted of sixteen members. The present committee and its duties, as listed in the April issue of ILLUMINATING ENGINEERING, is as follows:

OFFICE — To study the lighting requirements of office lighting tasks, develop suitable lighting recommendations and report thereon.

J. J. Neidhart, Chairman
G. F. Dean, Vice-Chairman

A. S. Alburyde	R. W. McKinley
C. L. Amick	G. G. Rae
C. T. Bakeman	T. H. Shepherd
L. M. Endres	Roger T. Waite
W. S. Fisher	G. P. Wakefield
W. E. Folsom	R. R. Wylie
C. W. Macy	R. L. Zahour

Occasionally one hears speculation on the possibility of some faction of the industry using persuasive influence in directing Recommended Practices and other Society activities along biased lines of thinking. In a technical Society such as ours, *any* such influence, in the minutest degree, would be *most* undesirable. It would be dangerous, not only to the Society but to the whole lighting industry, and to all the people we serve outside the industry. To know how ridiculous it is to suggest any semblance of influence affecting I.E.S. operations of any nature, it is necessary only to look at the names of the members of the Office Lighting Committee, for example. Their

(Continued on page 30A)

PORTLAND, MAINE, was site of meeting co-sponsored by I.E.S. and the Electrical Associates of Maine, April 5. Left to right: front row, Perley E. Weatherbee, Local Representative, I.E.S.; C. M. Snyder; back row, Harlow C. Skillins, President of the EAM; Lawrence S. Cooke and C. M. Holden.

THE PEMCO MERCURY VAPOR STREET AND HIGHWAY LUMINAIRE

Easy Maintenance! Snap-in reflector simplifies cleaning

This company's experience with street lighting dates back to 1882 . . . and you learn a lot about applications and special problems through the years. On top of this intimate knowledge, our luminaire offers these advantages: high light output efficiency, heavy cast aluminum housing, slip filter suitable for mounting on 1¼" or 2" bracket arm. We'll be happy to discuss your problem.

Pemco

America's Oldest
Street Lighting Manufacturer

PHILA. ELECTRICAL & MANUFACTURING CO.
1200 N. 31st Street • Philadelphia 21, Pa.
Be modern—live electrically

(Continued from page 28A)

affiliations in the industry are as follows:

Type of Organization	Number Members
Utilities	6
Fixture Manufacturers	4
Lamp Manufacturers	3
Glass Manufacturers	1
Industry Representation	
U. S. Government (GSA)	1
Large Insurance Company	1

This diversification of personnel is an assurance that no one man can exercise any major influence in the nature or text of a report. Ideas and opinions are often quite varied, to be sure. Specific points of contention do arise and must eventually be ironed out. For a meeting of the minds of members of the Committee, many meetings and much discussion is often required. This happened, certainly, with the Office Lighting Committee. However, where those whose opinions were mildly in disagreement to those who strongly opposed a certain important point, compromises were accepted in a sportsmanlike manner. But never once was a biased opinion expressed or any suggestions made which could be construed in any way to benefit an individual or a company. As a matter of fact, not a single member of the Office Lighting Committee ever tried to propose any such ideas.

In the preparation of the Office Lighting report, most controversial point discussed was the evaluation of comfort of seeing. It was felt by the committee that some form of tangible or "mathematical" system should be developed. All members agreed too that any comfort evaluation system presented should be kept as simple as possible, and be easy to use. With this in mind, it is not too difficult to imagine that a number of systems were proposed, some highly controversial, others too weak to support or consider.

Our Society has published in ILLUMINATING ENGINEERING, and in the I.E.S. Handbook, several comfort rating systems proposed by a number of our members. None of these was felt to be suitable for the new Office Lighting Practice, in the opinion of the committee. Consequently, after much deliberation, a new system is proposed, based on brightness limitations within a boundary set by two straight lines. As mentioned, this became the most controversial point of discussion and actually held up publication of the Practice for about a year, probably longer. All matters were long ago unanimously approved by the Committee, except this one point. There were at least two or three members of the committee who, even at the end, expressed dissenting votes. Be that as it may, the other members voted favorably for the new comfort rating. So, as in a jury where legal judgment is considered, the new system was overwhelmingly approved by the Office Lighting Committee. Likewise by Council, and so it is we have a new Office Lighting Practice.

At the beginning of this fiscal year, we thought our members would be interested in comments and internal operations of the Society. This became the purpose of "Operation I.E.S." If anyone has read this far in the article, would you be kind enough to send us a two cent postcard indicating that you have read one or more of the articles. Suggestions will be appreciated. We'd just like to know if anybody reads this stuff, so just a card is our objective now. GEORGE J. TAYLOR, *General Secretary.*

Student Awards Made in Residence Lighting Contest

Results of the Fifth Annual Lighting Design Competition for New York City High School students, sponsored by the New York Residence Lighting Forum, were announced at the Forum's Spring party June 5. The competition was open this year to girl students in the Academic and Vocational High Schools, and involved the planning of artificial lighting for a 3½ room New York City apartment. The competition was under the direction of Miss Marion Seitz, Chairman of the contest committee and Harry Lewis, for the Board of Education. Judges were Berlon Cooper, *Electrical Construction and Maintenance;* Miss Lillian Eddy, General Electric Co.; and Thomas Smith Kelly, Lighting Consultant.

Winning contestants are:

First Prize — Andrena Moreno Leal
Second Prize — Ann Zadra
Third Prize — Arlene Sabetsky
Honorable Mentions — Nilda Bonilla, Dory Orama, and Marilyn Sacrowitz

Representatives of the Board of Education and the school system attended the meeting, which was held at the Cooper Union Museum.

Farm Wiring Conference Sponsored by NEMA Subcommittee

More than 250 farm electrification and wiring specialists from industry, the U.S. Department of Agriculture, national farm organizations, colleges of agriculture and the farm and electrical press participated in the National Farm Wiring Conference, May 3 and 4, at the La Salle Hotel, Chicago.

The meeting was sponsored by the Farm Wiring Subcommittee, Farm and Rural Market Development Committee of the National Electrical Manufacturers Association. Presiding co-chairmen of the conference were the chairmen of the subcommittee and the committee, E. F. Luna of Anaconda Wire and Cable Co. and H. H. Watson of the Construction Materials Division, General Electric Co., respectively. Keynote speaker was S. J. Rosch, cable consultant of Anaconda Wire and Cable Co.

ABOUT PEOPLE

The appointment of **Charles A. Burton** to the newly created post of Regional Sales Vice President of Sylvania Electric Products Inc. has been announced. In his new assignment, Mr. Burton, who previously was general sales manager of the company's lighting division, is responsible for coordinating the overall sales program in the Middle West. His new headquarters are in Sylvania's Chicago sales offices at 2001 N. Cornell Ave., Melrose Park, Ill.

The Board of Directors of The Thompson Electric Co. has announced the election of **Thayer B. Farrington** as Chairman of the Board, **Robert K. Farrington** as President and General Manager, and **George H. Page** as Vice President of Sales. Mr. Page was also elected to the board.

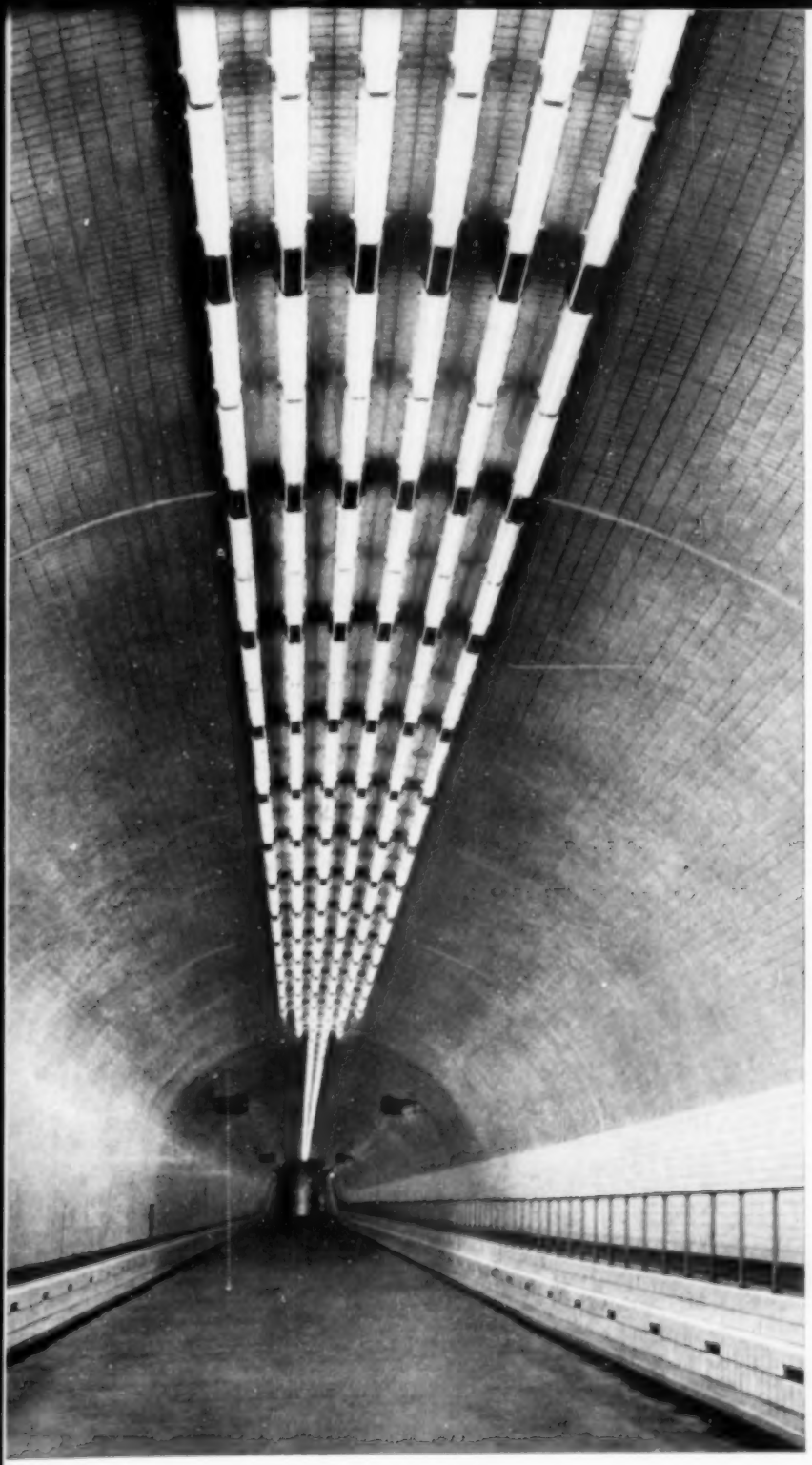
Robert H. Johannesen, president, Johannesen Electric Co., Inc., Greensboro, N. C., has received the Distributors Medal and Purse, given under the James H. McGraw Award for Electrical Men, at the opening session of the convention of the National Association of Electrical Distributors, June 12 in Atlantic City.

Russell R. Menard has been appointed to the post of Manager Marketing Administration in General Electric Co.'s Plastics Department. Mr. Menard will be located at the department headquarters, 2200 North 22nd St., Decatur, Ill.

Oscar P. Cleaver has received his second "Outstanding" award for his work as chief of the Electrical Engineering Department of the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Va. This latest award was presented for his high level of leadership and proficiency and for his ability to elicit the full support and cooperation of his subordinates. The first award, presented in 1954, was for his work in initiating a standardization of components of engine generators, for his work in the field of illumination, mine detection and infrared programs.

Warren H. Chase, Vice President of the Ohio Bell Telephone Co., was re-elected President of the Cleveland Engi-

(Continued on page 34A)



Better looking, better lighting

with luminaires of Du Pont LUCITE®

Lucite acrylic resin combines beauty with durability. It provides the lighting industry with a material that is superior for many types of lighting applications. Luminaires of LUCITE are strong, free from discoloration and dimensionally stable. Light in weight, they are easy to handle and install.

Nearly two miles of luminaires in the Baytown-LaPorte Tunnel in Texas demonstrate the superior efficiency of LUCITE. Manufactured by the Sunbeam Lighting Company of Los Angeles, California, and installed by Muhl Electric Limited of Houston, the luminaires of LUCITE provide high transmission of the entire visual spectrum. The LUCITE does not discolor and it is practically impervious to the effects of fumes, vapors and other tunnel conditions. The luminaires of LUCITE are easily maintained and strong enough to withstand high-pressure cleaning sprays. (LUCITE extruded by Plastic Process Company, Division of Monadnock Mills, Los Angeles, California.)

Du Pont LUCITE can be readily formed into desired shapes and is available in a wide range of transparent and translucent colors.

SEND FOR NEW FREE BOOKLET. This new 12-page illustrated booklet describes all the latest property and application data on LUCITE acrylic resin for lighting. For your free copy, write to E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room 287, Du Pont Building, Wilmington 98, Del.

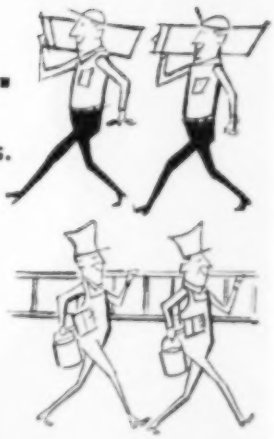
• This "Quality Controlled" label may be used only by qualified extruders of Du Pont LUCITE acrylic resin. It assures the lighting industry that the extruded material conforms to standards for low shrinkage and uniform caliper established by E. I. du Pont de Nemours & Co. (Inc.).

Quality Controlled

DU PONT

BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY

THE LIGHTS THAT GO IN WHEN THE PAINTERS GO OUT...

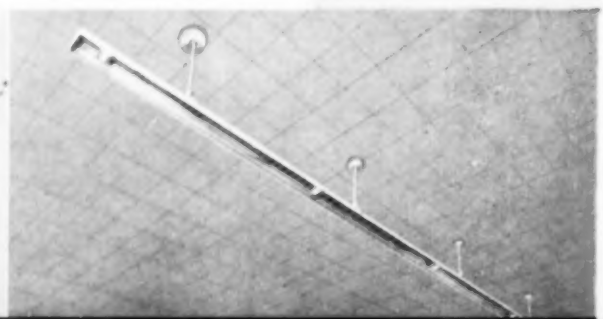


No On-Job Storage. No Paint-Spattered Fixtures. 50% Savings on installation costs.

Gibson ORTHO Fixtures need not be stored on the job where they're in the way of workmen and in danger of damage. Actually, Gibson ORTHO Fixtures can be delivered to the job the day before occupancy, because each fixture simply snaps into place in a matter of seconds, just as it comes from the box —sparkling clean, factory-fresh.

If you're interested in better lighting with savings of more than 50% on installation costs, then you really ought to know more about the Gibson ORTHO Line for industrial and commercial applications. Drop us a line. We'll send you the whole story.

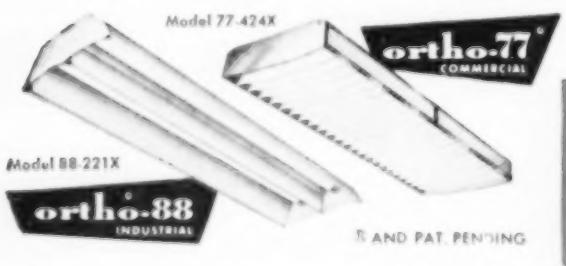
1. WIRED ON THE FLOOR • A special channel (UNI-RACE) of telescoping 4' or 8' sections is assembled and wired on the floor, then lifted as a unit and mounted directly on joists, I-beams or stems. Saves hours of labor.



2. READY FOR THE FIXTURES • The UNI-RACE in place showing the built-in receptacles at 48" intervals. While the building is under construction, it will serve as a source of power for tools and temporary lighting.

3. SNAP—AND IT'S UP! • When the painters have left, the fixtures can be delivered to the building and snapped into place as fast as they are unboxed. Each fixture has a built-in plug which engages the receptacle in the UNI-RACE. Fixtures align themselves automatically.

4. VARIABLE SPACING • Fixtures may be installed in continuous rows or spaced at intervals of 4, 8, 12 or more feet. Units may be added, removed or rearranged any time without tools. Special "fill-in" sections close the UNI-RACE where no fixtures are mounted.



® AND PAT. PENDING

Gibson LIGHTING

GIBSON Manufacturing Co.

40 feet up...yet all the light you need at "SEE" level!

Lighting fixtures and lamps must be way up high in airplane factories, steel mills, sports arenas and similar buildings. This means that lamps must be unusually powerful for sufficient light to reach the floor area.

Among the most efficient light sources ever developed for "high bay" uses is the Sylvania Mercury Vapor Lamp. It gives brilliant blue-white light that has high illuminating power. What is more, this remarkably efficient lamp gives more light per operating dollar than practically any other lamps suitable for high bay operation.

For special applications, where color appearance is important, the Sylvania Color-Improved Mercury Vapor Lamp is particularly useful.

Because of their outstanding economy of operation and high output of usable light, Sylvania Mercury Vapor Lamps are widely used for street and highway lighting, too . . . helping to keep your taxes down, making nighttime driving safer.

If you have a lighting problem you believe Sylvania Mercury Vapor lighting will solve, phone or write your nearest Sylvania office. For technical and application data, write directly to:

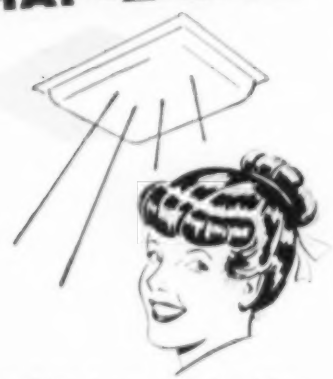
SYLVANIA ELECTRIC PRODUCTS INC.
Lighting Division, Salem, Mass.
In Canada:
Sylvania Electric (Canada) Ltd.
University Tower Building, Montreal

SYLVANIA

...fastest growing name in sight

LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

CASH IN ON THE
"Pink Light"
PROMOTION
with
HAP-E-LITE



Hap-E-Lite is an exclusive Alkco fixture which actually achieves what pink bulbs only promise.

- Provides soft warm tones.
- Enhances people's complexion.
- Flatters furnishings.
- No color distortion.
- Available in most Alkco incandescent fixtures.
- Hap-E-Lite builds profits and reputation for those who recommend it.

SELL A FIXTURE
INSTEAD of a LIGHT BULB

Write for Descriptive Folder

ALKCO MFG. CO.

812 stock incandescent and fluorescent fixtures, recessed and surface-mounted—plus highest quality custom work too!

4242 N. Lincoln Ave. • Chicago 18, Ill.

(Continued from page 29A)

neering Society, May 10, at a meeting of the Board of Governors. Re-elected with Mr. Chase were **Willard C. Brown,** General Electric Co., first Vice-President; and **Robert C. Trundle,** Trundle Consultants, Inc., Treasurer. **Harvard H. Gorrie,** Bailey Meter Co., was elected second Vice-President.

Charles S. Stodter has been named Executive Secretary of the Society of Motion Picture and Television Engineers assuming his new position at Society headquarters in New York early in July. Mr. Stodter was formerly Senior Research Investigator with the Institute for Cooperative Research at the University of Pennsylvania. He succeeds **Boyce Nemec,** who recently resigned from SMPTE to open a management consulting service.

The Miller Co. has appointed **William N. Hancock** as sales representative in the Cleveland area territory. Mr. Hancock was formerly in the Utica, Ohio, and the Eastern Pennsylvania territories for the company.

Robert E. Gordon has been appointed Sales Engineer and representative for Leadlight Fixture Co., Oakland, Calif. Mr. Gordon was formerly lighting salesman for T. L. Rosenberg Co.

Century Lighting Inc. announces the opening of a Southern branch, located at 1485 N. E. 129th St., North Miami, Fla. **George Gill** has been named as manager of the new office.

NEW MEMBERS

At the meeting of the I.E.S. Council held at New York, N. Y. on June 14, 1956, the following were elected to membership. Names marked * are transfers from Associate Member Grade.

ARIZONA SECTION

Associate Member:
Gledhill, E. R., Arizona Public Service Co., Casa Grande, Ariz.

CAPITAL SECTION

Member:
*Goodman, Benjamin, National Electric Wholesalers, Washington, D. C.

Associate Members:
Leache, L. M., Potomac Electric Power Co., Washington, D. C.
Melton, J. C., Potomac Electric Power Co., Washington, D. C.

CENTRAL OKLAHOMA CHAPTER

Associate Member:
Hall, J. F., Service Electric Supply Co., Oklahoma City, Okla.

CHICAGO SECTION

Associate Members:
Brown, R. W., Consulting Engineering Service, Champaign, Ill.
Engstrom, J. P., Hotpoint Co., Chicago, Ill.
Hetra, John, St. Arnaud Electric Co., E. Chicago, Ind.
Holtz, Norman, Alkco Mfg. Co., Chicago, Ill.

(Continued on page 36A)

Advance Transformer Offers World's Most Complete Line of Quality Fluorescent Lamp Ballasts

Through outstanding engineering developments and modern manufacturing facilities, ADVANCE TRANSFORMER COMPANY has become the world's largest manufacturer devoted exclusively to the production of quality fluorescent lamp ballasts. These precision built, power regulating instruments supply exacting amounts of electrical energy for the efficient operation of all fluorescent lamps and are aptly called "THE HEART OF THE LIGHTING INDUSTRY."

Continuing research and constant new developments in both engineering and manufacturing divisions have made possible the introduction of many new ballasts with exclusive patented features. Thus, ADVANCE provides lighting equipment manufacturers, designers, architects, engineers, contractors and other fluorescent lamp ballast users the world's most extensive line of fluorescent lamp ballasts. When you use ADVANCE, there is a ballast for every specific purpose, never a need to compromise.

ADVANCE ballasts are listed by Underwriters' Laboratories, Inc., meet the Canadian Standards Association requirements and many meet or exceed Certified Ballast Manufacturers' specifications. Specify ADVANCE to be sure to get the ballasts with the "plus factors" that have built the world's largest company devoted exclusively to the manufacture of fluorescent lamp ballasts.

The Advance Transformer Company will replace, at no charge, any ADVANCE fluorescent lamp ballast which becomes inoperative within two years from date of manufacture, provided the conditions of ballast operation have conformed to the company's recommendations and the inoperative ballast is returned to an authorized ADVANCE Service-Stocking Distributor.

For anyone who manufactures, specifies, installs or uses fluorescent lighting, ADVANCE TRANSFORMER COMPANY has prepared helpful literature which they will gladly send without cost or obligation.

Fluorescent Lamp Ballast Buyer's Guide

This eight-page brochure gives data on the world's most complete line of Fluorescent Lamp Ballasts. It includes specifications, wattage, watt loss, circuit voltage, dimensions, weight, etc. This brochure is an invaluable aid for specifiers and users of fluorescent lamp ballasts.

Fluorescent Lamp Ballast Cross Reference Guide

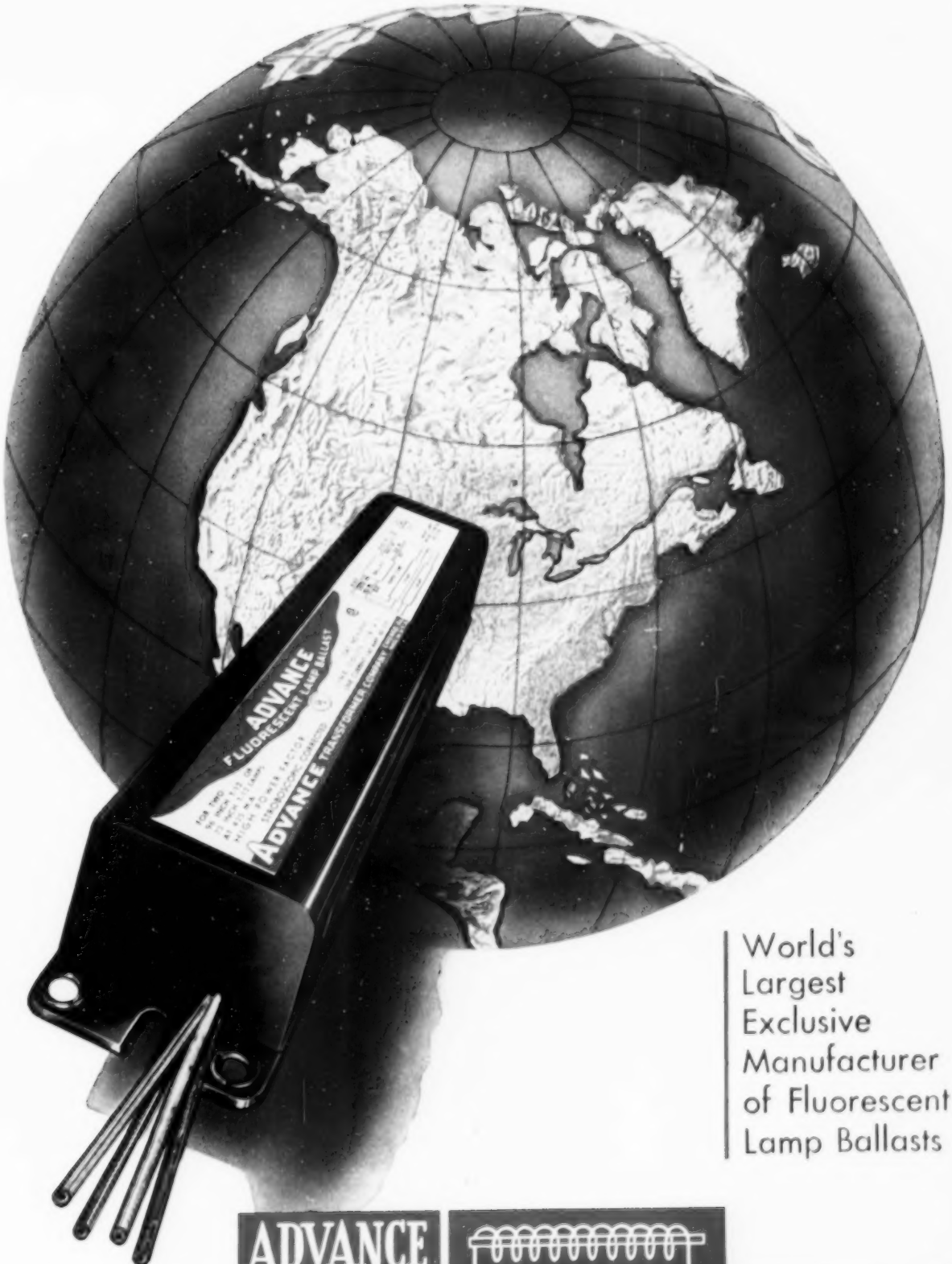
This helpful guide lists many popular ballasts by catalog number and the ADVANCE ballast that should be used whenever ballast replacement becomes necessary. It is an invaluable reference chart that saves time and money for all users of fluorescent lamp ballasts.

Service-Stocking Distributor Plan and List of Distributors

This is a six-page color brochure that lists, by city and state, more than 550 distributors who carry a stock of ADVANCE Fluorescent Lamp Ballasts, to provide immediate replacement service for *ballasts of any make* that become inoperative.

You may receive a copy of one or all of these brochures by contacting ADVANCE TRANSFORMER COMPANY, Marketing Division, 2950 North Western Avenue, Chicago 18, Illinois.

(Advertisement)



World's
Largest
Exclusive
Manufacturer
of Fluorescent
Lamp Ballasts

ADVANCE

World's Largest Exclusive Manufacturer of Fluorescent Lamp Ballasts

TRANSFORMER CO.

2950 NO. WESTERN AVE. CHICAGO 18, ILL. U.S.A.

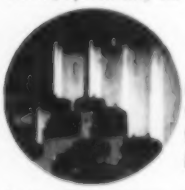
Ask these questions, too, when you judge a fluorescent lamp . . .

Is your investment protected?

Check Westinghouse Fluorescent Lamps against any other brands you are now using. Check them for maintained brightness, long life, uniform appearance. If you are not entirely satisfied on all counts, your full purchase price will be refunded.

Is it built with tailored glass?

Quality of glass in a fluorescent lamp directly affects lamp performance. Westinghouse makes all of its own fluorescent lamp glass, tailoring it from silica to finished tubing specifically for fluorescent service.



Is it the correct type, size and color for the lighting job to be done?

In the Westinghouse fluorescent family of 200 different lamps—including Slimline and Rapid Start—there's a type and size precisely right for every office, plant and merchandising application. Colors include seven different shades of "white" alone.

For the full story on how to get more for your money in fluorescent light, contact your Westinghouse Lamp Representative. "You can be sure if it's Westinghouse."

WATCH WESTINGHOUSE!

WHERE ***BIG*** *THINGS ARE HAPPENING FOR* ***YOU!***

(Continued from page 34A)

Horwitz, L. I., Leonard Electric Co., Chicago, Ill.
Kramer, C. R., Kraft Foods Co., Chicago, Ill.
Palifferro, Benjamin, Efengee Electric Supply, Chicago, Ill.
Parthun, E. H., Dryden Rubber Co., Chicago, Ill.
Schramm, R. L., Plax Corp., Chicago, Ill.
Warner, R. M., Westinghouse Electric Corp., Chicago, Ill.

CLEVELAND SECTION

Member
Blain, G. E., Stickle & Associates, Cleveland, Ohio.

Associate Members
Arko, L. J., Goodyear Tire & Rubber Co., Akron, Ohio.
Belb, W. A., Goodyear Tire & Rubber Co., Akron, Ohio.
Borzik, J. J., Goodyear Tire & Rubber Co., Akron, Ohio.
Lowell, W. L., General Electric Co., Cleveland, Ohio.
Metcalf, H. S., Garden City Plating & Mfg. Co., Cleveland, Ohio.
Shackson, R. H., Richard Hawley Cutting & Associates Inc., Cleveland, Ohio.

CORNHUSKER CHAPTER

Associate Members
Klanderud, Bob, Design, Inc., Sioux City, Iowa.
Marsh, E. J., Sioux City Optical Co., Sioux City, Iowa.
Potter, Elmer, Potter Electric Shop, Harlan, Iowa.
Shoup, J. D., Crescent Electric Supply Co., Sioux City, Iowa.

EASTERN NEW YORK SECTION

Associate Members
Cone, W. B., Westinghouse Electric Corp., Albany, N. Y.
Katzel, A. S., Ask Electric Co., Albany, N. Y.

EASTERN PENNSYLVANIA SECTION

Member
McLane, J. T., American Newspaper Publishers Assn. Research Institute Inc., Easton, Pa.

FOREIGN NON-SECTION

Associate Member
Morales, R. J., Oficina Tecnica Morales, C. A., Caracas, Venezuela.

GOLDEN GATE SECTION

Members
Jankelson, M. H., Incandescent Supply Co., San Francisco, Calif.
*Keyes, J. E., Benjamin Electric Mfg. Co., San Francisco, Calif.

Associate Members
Baker, G. M., Graybar Electric Co., Inc., San Francisco, Calif.
Krieger, C. H., Clyde E. Bentley, Consulting Engineer, San Francisco, Calif.

INDIANA SECTION

Members
*Peloquin, R. L., Westinghouse Electric Corp., Indianapolis, Ind.
*Wiese, A. H., Benjamin Electric Mfg. Co., Des Plaines, Ill.

Associate Members
Eckhart, P. V., General Electric Co., Indianapolis, Ind.
Marks, C. H., Indiana & Michigan Electric Co., Marion, Ind.
Tortorello, R. P., Sylvania Electric Products, Inc., Indianapolis, Ind.

Student Members
Adams, R. W., Purdue University, W. Lafayette, Ind.
Cepni, Jon, Purdue University, W. Lafayette, Ind.
Cooper, C. B., Purdue University, W. Lafayette, Ind.
Garrett, L. A., Purdue University, W. Lafayette, Ind.
Kam, B. W., Purdue University, W. Lafayette, Ind.
Lemons, T. M., Purdue University, W. Lafayette, Ind.
Martin, C. L., Purdue University, W. Lafayette, Ind.

INLAND EMPIRE CHAPTER

Associate Member
Crow, K. J., Public Utility District of Grant Co., Ephrata, Wash.

IOWA SECTION

Member
Obele, R. F., Crescent Electric Supply Co., Waterloo, Iowa.

Associate Member
Dietz, Mel., Crescent Electric Supply Co., Davenport, Iowa.

Student Member
Engle, R. C., Iowa State College, Ames, Iowa.

MARITIME CHAPTER

Associate Members
Wade, D. M., Richards Electric, Fredericton, N. B.
Wilcox, E. J., Electrolier Mfg. Co. Ltd., Montreal, Que.

MARYLAND SECTION

Member
*Hilmer, F. E., Reliable Electric Co., Baltimore, Md.

Associate Member
Esposito, C. E., Charles E. Esposito, Baltimore, Md.

MIAMI VALLEY CHAPTER

Associate Member
Dittrich, C. J., General Electric Supply Co., Dayton, Ohio.

MID-SOUTH CHAPTER

Student Members
Johnston, J. L., Southern College of Optometry, Memphis, Tenn.
Perkins, N. G., Southern College of Optometry, Memphis, Tenn.
Persons, L. E., Southern College of Optometry, Memphis, Tenn.

MILWAUKEE SECTION

Member
O'Connor, A. J., 1840 N. Lake Drive, Milwaukee, Wis.

Associate Members
Brenne, Marilyn L., P. O. Box 303, Manitowoc, Wis.
Gillitzer, John, Gillitzer Electric Service, Inc., Milwaukee, Wis.
Shatola, G. E., Incandescent Service Co., Milwaukee, Wis.

MONTREAL SECTION

Members
Black, C. M., Amalgamated Electric Corp., Ltd., Montreal, Que.
Hanley, A. J., Paul De Guise, Consulting Engineer, Montreal, Que.

NEW ENGLAND SECTION

Members
Dormitzer, Henry, Dormitzer Electric & Mfg. Co., Inc., Cambridge, Mass.
*Forster, C. J., Jr., Western Massachusetts Electric Co., Greenfield, Mass.
Fournier, E. E., General Electric Supply Co., Springfield, Mass.
Swann, C. B., Pittsburgh Reflector Co., Marshfield, Mass.

Associate Members
Baker, E. F., The Narragansett Electric Co., Providence, R. I.
Crosby, P. M., Cambridge Electric Light, Cambridge, Mass.
Dean, M. H., M. H. Dean Co., Springfield, Mass.
Gansis, C. A., Western Massachusetts Electric Co., Greenfield, Mass.
Komlosi, E. J., General Electric Co., Pittsfield, Mass.
Turner, J. M., City of Springfield, Springfield, Mass.
Winters, S. C., Winters Electrical Co., Inc., Springfield, Mass.

NEW ORLEANS SECTION

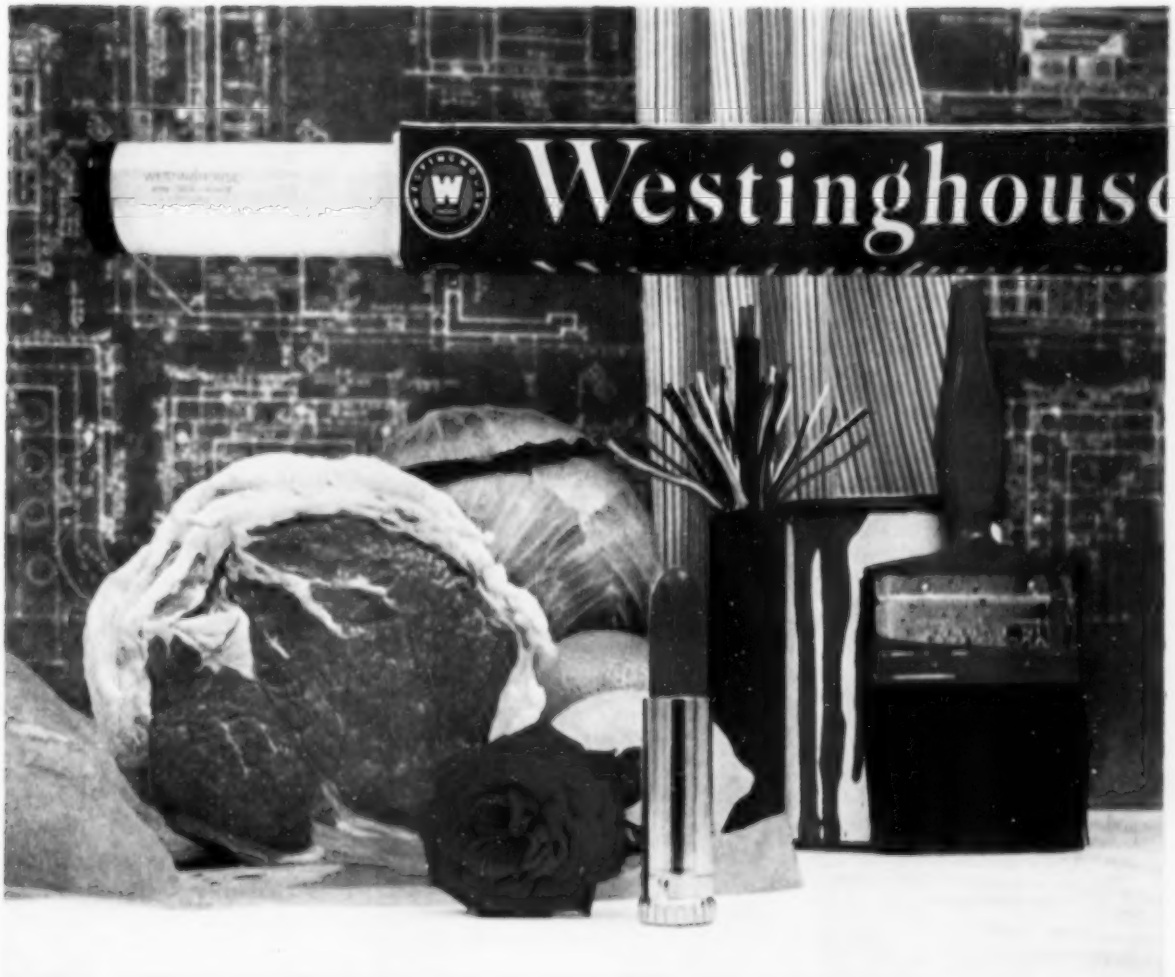
Associate Members
Lauchsheimer, R. J., Jr., W. J. Milner & Associates, New Orleans, La.
Wheelahan, K. J., Jr., New Orleans Public Service Inc., New Orleans, La.

NEW YORK SECTION

Member
*Kerr, John, Jr., Public Service Electric & Gas Co., Newark, N. J.

(Continued on page 38A)

how to judge a fluorescent lamp . . . point no. **5**



ask about COLOR RENDITION

If you're like most businessmen today, you know how the proper use of color can speed a lagging production line, work wonders with office morale, give merchandise extra sales appeal. What you may not know, however, is that the color of any surface—be it desk top or cabbage leaf, electrical lead or your secretary's complexion—is largely determined by how that surface is lighted. And that light just right for Job A may be all wrong for Job B. Westinghouse fluorescent lamps—available in seven different shades of "white" alone—offer you precisely the proper color of light for jobs from A to Z. "You can be sure if it's Westinghouse."

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING FOR **YOU!***

Recessed lighting creatively engineered!

kurt versen

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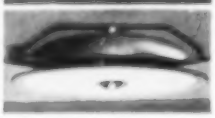

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(Continued on page 42A)

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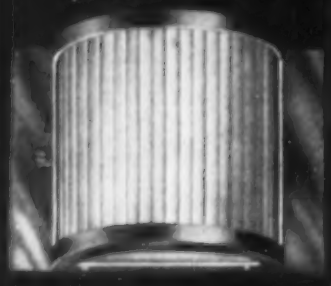

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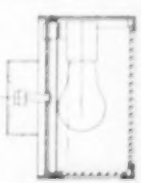

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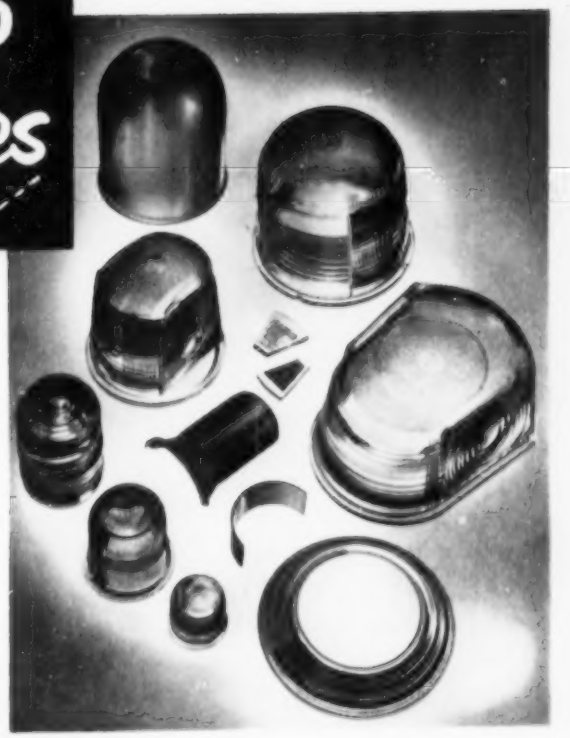

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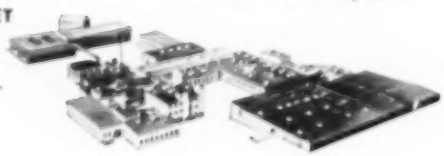

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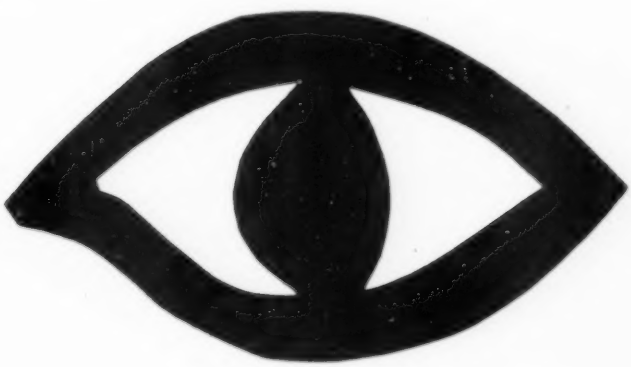

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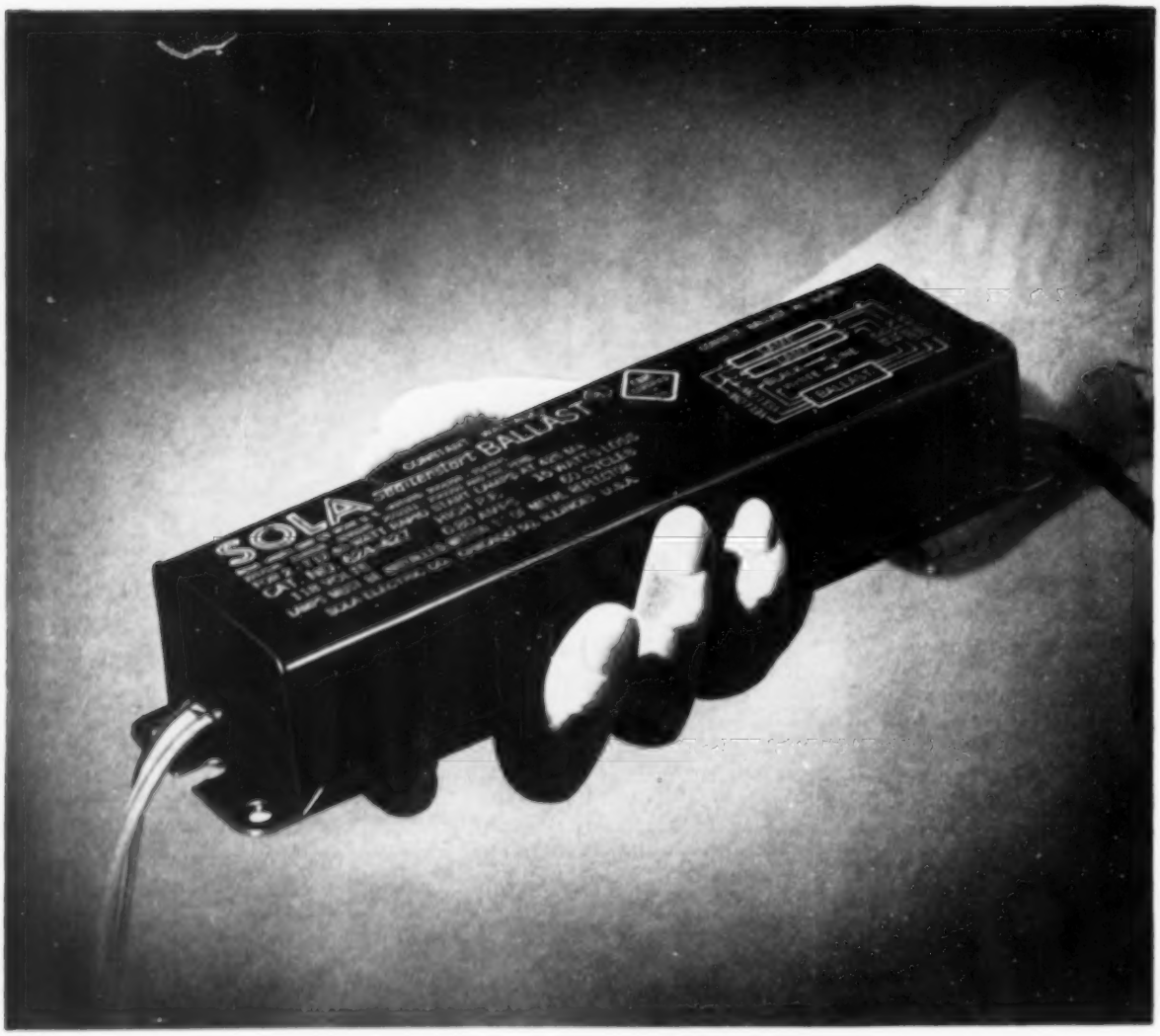

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Typical of the quality of the complete line of Sola Fluorescent Ballasts is a new two-lamp design for 40WT12 rapid-start lamps. This new ballast (Cat. No. 624-427) provides small size *plus* new standards of coolness and quietness for its specific duty.

COOL OPERATION: ETL tests show copper heat rise is only 50°F. Low temperature rise results in exceptionally cool operation for ballasts of this type and size.

QUIET OPERATION: Exclusive Sola methods for core-and-coil assembly, case design, and compounding produce operational quietness exceeding that of other leading ballasts designed for similar duty.

Your area representative, listed below, will be happy to provide further information for you. He's one of a nationwide sales organization maintained by Sola Electric Co. to provide you with prompt service.

SOLA *Fluorescent* **BALLASTS**

CBM CERTIFIED by ETL

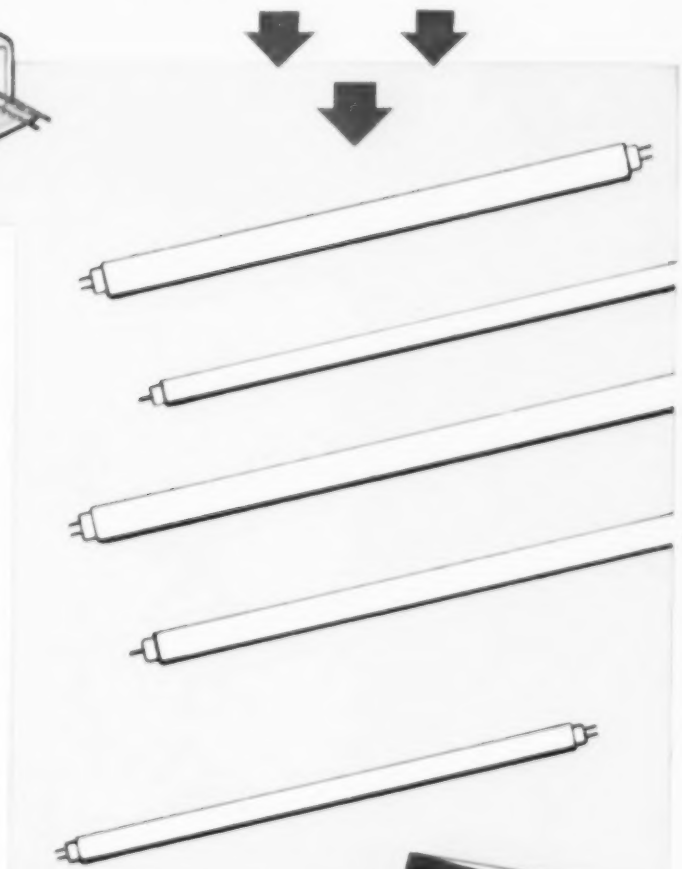
UL

CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • **LIGHTING TRANSFORMERS** for All Types of Fluorescent and Mercury Vapor Lamps. • **SOLA ELECTRIC CO.**, 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 • PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3334 • CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400 • KANSAS CITY 2, MO.: 406 W. 34th St., JeRerson 4382 • LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431 • TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4334 • Representatives in Other Principal Cities*

CERTIFIED CBM BALLASTS

...give you more economical Fluorescent Lighting

because they are "Tailored to the Tube"



Every type and size of fluorescent tube has its own specific electrical requirements. Thus, to get ideal performance and lighting economy, it is essential that the ballasts provide precisely the electrical needs of the tubes they operate.

CERTIFIED CBM BALLASTS are "Tailored to the Tube." Built to exacting specifications, then tested and checked by ETL, an independent agency, CERTIFIED CBM BALLASTS are a dependable assurance of both satisfactory and economical fluorescent lighting.

Certified CBM Ballasts

PROVIDE:

LONG BALLAST LIFE
FULL LIGHT OUTPUT
LONG LAMP LIFE
TROUBLE-FREE OPERATION

all of which contribute to easier maintenance and fluorescent lighting economy.

Eight of the country's leading manufacturers of ballasts make CERTIFIED CBM BALLASTS. Participation in CBM is open to any manufacturer who wishes to qualify.

Send for free booklet, "Why It Pays to Use CERTIFIED CBM BALLASTS in Fluorescent Lighting Fixtures."

CERTIFIED BALLAST MANUFACTURERS
2116 KEITH BLDG., CLEVELAND 15, OHIO

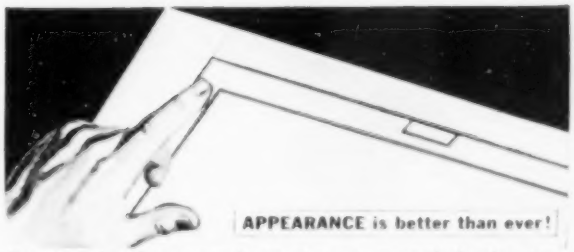
Look what happens when you specify

BENJAMIN Troffer Lighting

Things really start to happen when you specify money-saving, new Benjamin Troffers. Lighting maintenance expense is cut. Low-ceilinged rooms get a new improved light treatment. Annoying glare is banished. There's a brand new freedom of architectural expression and lighting layout. Shown here are a few of the advanced Benjamin features that help to make all this happen at the lowest possible cost per year. Investigate Benjamin Troffer Lighting for schools, stores, offices and factories . . . all things considered they're the Better Lighting Choice.

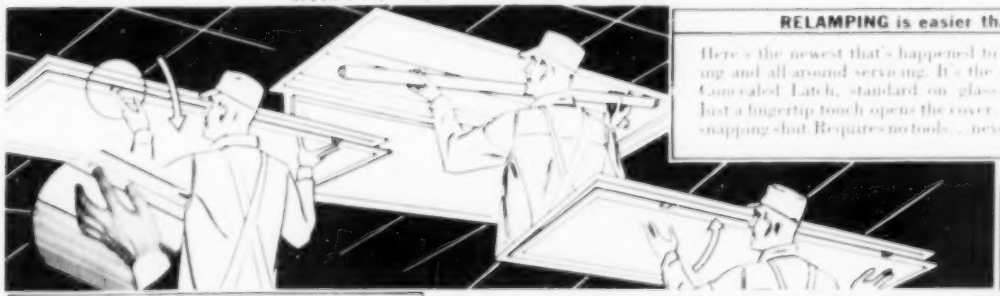
BENJAMIN ELECTRIC MFG. CO., DES PLAINES, ILLINOIS

Sold Exclusively Through Electrical Distributors



APPEARANCE is better than ever!

Greater ceiling beauty can happen to any room with the slim, trim design of Benjamin Troffers. A seamless frame, which shows no visible marks where the cover is joined, and concealed latches and hinges, make possible smooth, uninterrupted lines.



RELAMPING is easier than ever!

Here's the newest that's happened to speed up relamping and all around servicing. It's the Benjamin DeLuxe Concealed Latch, standard on glass-enclosed troffers. Just a fingertip touch opens the cover . . . closes by simply snapping shut. Requires no tools . . . never needs servicing.

TROFFER SELECTION is greater than ever!

There's no need to compromise size, style or type of installation when you specify Benjamin Troffers! Any architectural effect you desire can be made to happen with this wide choice: 12" and 24" widths; 4' and 8' lengths; 2' x 2' for fill-ins; wide range of glass and plastic covers or louvers; six different mounting styles.

Certified Lighting